ACKNOWLEDGMENTS

Even more than with previous books I've written, the number of people who assisted and encouraged me throughout a decade of research, writing, and editing was considerable.

None of this would have been possible without the gracious assistance of archivists and librarians at the Library of Congress, the Getty Research Institute, and the Smithsonian's Archives of American Art. My special thanks to Henry Lowood, Jessica Gambling, Jeremy Grubman, and Lois White. In addition, I was helped by three student research assistants—Clare Kim, Naomi Kuromiya, and Viola Ardeni—who tracked down archival materials with considerable skill and persistence.

I am especially grateful to the archivists and librarians who helped me locate research materials and, when time was pressing, secure images and permissions. I want to especially acknowledge Jessica Gambling and Piper Severance at the Los Angeles County Museum of Art and Emily Park and Virginia Mokslaveskas at the Getty Research Library for easing my acquisition of images for the book. Mark Hanauer generously contributed a photograph for the dustjacket. Matthew Christensen did a superb job as copy editor. Especial thanks go to Katie Helke and her colleagues at the MIT Press who helped shepherd this book through acquisition, production, and completion.

Two fellowships from the Smithsonian Institution—one from the National Air and Space Museum (in 2015–2016) and another from the Lemelson Center at the

National Museum of American History (2018–2019)—came at just the right times in the writing process.

Heather Krebs, the late Jack Masey, A. Michael Noll, Eugene Epstein, John Holloway, Ruth Waldhauer, Elsa Garmire, and Robert Kieronski all shared materials from their personal collections. In addition, Roger Malina and Julie Martin kindly provided unparalleled access to historical documents, family photographs, and artworks while also swiftly responding to many questions and requests for clarification. While they may not agree with all of my conclusions, the resources they shared helped build the foundation this book rests upon.

Friends and associates who offered ideas, shared research materials, read excerpts, and talked with me about this book project include Ann Johnson (1965–2016), Lee Vinsel, Meg Rotzel, Hyungsub Choi, David Brock, Jeanne C. Finley, Steven Duval, Jimena Canales, Anne Collins Goodyear, Amy Slaton, Peter Sachs Collopy, Dawna Schuld, Trevor Paglen, Fred Turner, Roger Malina, Eddie Shanken, Peter Westwick, John Blakinger, Julia Buntaine Hoel, Oliver Gaycken, Douglas Kahn, Asif Siddiqi, Stephen Nowlin, Amy Heibel, Peggy Weil, Andres Burbano, Michael Naimark, Fraser MacDonald, Fabrice Lapelletrie, Suman Seth, Evelyn Hankins, Johan Kärnfelt, Matthew Shindell, and David Kaiser. I'd also like to acknowledge colleagues in the University of California Santa Barbara's Media Arts and Technology Graduate Program, whose work at the art and engineering interface has given me much to think about. My thanks to you all and anyone I may have forgotten.

Three wonderfully kind colleagues took time from their own projects to read a draft of the entire book. Michael Gordin suggested creative ways of thinking about connections between the terrain of art history and more-familiar narratives about technology and science. Bruce Robertson likewise expanded my understanding of the histories of the modern visual arts and dance. And Matthew Wisnioski graciously provided detailed comments on the manuscript and suggestions as to new archival sources.

And, finally, to Nicole—I know, I know . . .

W. Patrick McCray
April 2020
Santa Barbara, California
and Fort Collins, Colorado

INTRODUCTION: SCHEMATICS

> The history of science is riddled with chance discoveries, discoveries that link science and art in a common irrationality.[1]
>
> Douglas M. Davis, 1968

Imagine you have a long, thin piece of plastic string. Now attach this spaghetti-like strand to a small electric motor. Then, wire this motor to an Ethernet cable so that whenever digital packets of information—an email, a music download—stream through the cable, the motor gives a tiny tug and makes the string twitch.

This was *Live Wire*, created by Natalie Jeremijenko in 1995 when the internet and the World Wide Web were still unexplored realms for most people.[2] For years, *Live Wire* was displayed in the corner of a busy hallway at Xerox's Palo Alto Research Center just off Stanford University's sprawling campus. When local network traffic was low, *Live Wire* remained relatively calm. But when the data flow surged from a trickle to a torrent, the eight-foot-long plastic string literally hummed and whirled with activity. A practical and tangible marker of the disembodied data streaming through cyberspace, Jeremijenko's creation could capture someone's attention or just as easily pass unnoticed. Unlike frenetic, real-time displays of network traffic, *Live Wire* was "calm technology," an artwork-as-instrument that provided useful information to people in the offices around it without being too obtrusive.[3]

Jeremijenko built *Live Wire* as both application and art. She, likewise, a hybrid, studying physics, chemistry, and fine arts in Australia before moving to the San

Francisco Bay Area and consulting for Xerox's "ubiquitous computing" initiative.[4] Jeremijenko later combined graduate training in design and engineering at Stanford with fellowships at the Exploratorium—an innovative science museum in San Francisco—and other such places. After getting her PhD in computer science and electrical engineering at the University of Queensland, she secured a tenured position at New York University where she built an international reputation as a self-described "thingker" who capably combined art and engineering.[5]

Writers' descriptions of Jeremijenko were as vague as her professional credentials were varied. In 2006, *Salon* labeled her an "artist as mad scientist."[6] Five years later, an engineering education publication reversed course and christened Jeremijenko a "scientist as mad artist."[7] Another magazine eschewed the trope of insanity altogether and called her an "engineer for the avant-garde," but then confused matters by noting, "it's art, all right. But is it engineering?"[8] Further categorical complications and a little feather ruffling ensued when Jeremijenko told the *New York Times* that the art world was a "prissy little thing over in the corner, while the major cultural forces" that really shaped people's everyday experiences were "being determined by technoscience."[9]

Artwork as opposed to instrument or experiment? Engineer versus artist? Even today, we often see these as two different cultures separated by impervious walls. But some fifty years ago, the borders between technology and art, long imagined as solid, began to be breached, even if they have not yet melted entirely melted into air. New collaborative communities of engineers, scientists, and artists, fragile at first but eventually durable enough to take root in universities, museums, and companies worldwide, emerged. This transformation's history spills beyond the frame of art and technology, providing color and depth to our picture of the era's broader economic and social contexts.

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Six decades ago, the professional boundaries between engineer and artist—their communities, activities, institutions, skills, and shared interests—seemed much more unyielding than they are today. Hadn't Charles Percy (C. P.) Snow, the British chemist turned government advisor and novelist, famously generalized that Great Britain's intellectuals and political leaders were conversant with the arts and humanities but remained willfully ignorant about technology and science? Even worse, as Snow claimed in 1959, the gaps between humanists and scientists—or, as labeled more recently, between "fuzzies" and "techies"—had dangerously widened to the point of mistrust and incomprehension.[10] Although Snow aimed his critiques primarily at humanists and scientists, his categories expanded to include artists and engineers.

Today, "bridging the two cultures" is, at best, a synecdoche for some form of interdisciplinarity. At worst, it's a cliché overused by academic administrators and business leaders. More valuable when viewed in its historical context than for its analytical heft, Snow's claims retained rhetorical punch well into the 1960s. Once removed from its original British setting, "two cultures" became a phrase in the United States that helped generate research funds, launch government-funded studies of creativity, and provoke calls to revise university curricula. Art-and-technology advocates imagined their intervention could help solve the "two cultures problem," or at least lessen the animus. Viewed by some as too important to be left just to artists, making art was something to which engineers and scientists could and should contribute. Advocates claimed collaborative experiments, which allowed artists to explore new aesthetic possibilities that technologies such as lasers, microprocessors, and computers afforded, could electrify artworks while rewiring the work of making art itself. These activities, they argued, could simultaneously rehabilitate the public's increasingly negative view of technology and its presumed masters: engineers.

Throughout the 1960s and up to today, artists and engineers engaged in "hybrid practices" that wired the realms of art, technology, and science together and generated a new creative culture.[11] Their collaborations, some fleeting and others long-lived, often produced thoughtful, aesthetically sophisticated, and visually arresting works of art. It also sometimes sparked new companies, patents, and commercial innovations. Divergent in their interests and professional knowledge, engineers and artists learned to speak one another's languages, though at times imperfectly. By working as partners—even if the arrangements were occasionally unequal—artists and engineers came to appreciate and sometimes even adopt each other's approaches to experimentation. I aim to explore the diverse strategies they adopted to build a new kind of creative sensibility.

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Well before the 1960s, artists had sporadically mingled with engineers and scientists. Artists, of course, relied on a range of tools while also experimenting with new technologies as they became both available and accessible (the former does not entail the latter). Artists' embrace of photography in the mid-nineteenth century—a time when the word “technology” meant the *study* of the so-called practical arts, and not the products themselves—suggests how divides between art and technology are themselves historical constructs. Technology also offered potent subject matter as artists such as George Inness and Charles Sheeler recorded, in very different ways, the landscapes of American industry. Sometimes artworks critiqued modern technology’s status and power. Diego Rivera’s famous Detroit Industry Murals, made during the Great Depression, portrayed workers at Ford Motor plants along with the transformative power of science-based research. Thirty years later, Ed Kienholz used flashing lights, a telephone handset, and complicated-looking dials to make *The Friendly Grey Computer* resemble some sort of computing thing. But Kienholz constructed it in the approachable shape of a traditional rocking chair (and included what appear to be a child’s feet, poking outward).

Technology itself stimulated both artists and artistic movements. In 1909, the Italian poet Filippo Tommaso Marinetti launched the futurist movement with a manifesto published in *Le Figaro*. Although the futurists glorified the speed and violence of automobiles and airplanes, they saw technology more as an aesthetic ideal and did not seek out collaborations with engineers. A decade later, Vladimir Tatlin, working in Russia under completely different political circumstances, articulated an artistic philosophy that informed the constructivist movement. He envisioned the liberation of modern materials and industrial techniques from the realm of factories to be used by artists. Like the futurists, Tatlin admired machine aesthetics, yet he imagined making art that served the state. For instance, after the Russian Revolution, Tatlin revealed his model for a *Monument to the Third International*. Designed as an amalgam of steel, glass, and revolutionary sentiment, the completed monument would have combined sculpture and architecture with mechanical movement and the projection of propaganda via electronic media. Intended to surpass the Eiffel Tower but never realized, building Tatlin’s *Monument* would certainly have demanded engineers’ expertise. In fact, when Tatlin exhibited a twenty-foot-tall model of *Monument* in 1920, the red banner suspended above it commanded, “Engineers, create new forms.” Despite high-minded aspirations, productive partnerships between artists and engineers did not emerge as a feature of the constructivist movement or Soviet industry.[12]

After the chaos of World War I, German artists and architects considered how artists might productively work with manufacturers to foster social reform. The Bauhaus, started in 1919 by architect Walter Gropius, sought to fuse art with industrialization by integrating aesthetics and functionality into design and architecture. In his founding manifesto, Gropius stated his wish to end artists' exile from the worlds of craft and industry by conjoining the fine and applied arts. Four years later, when Bauhaus members organized their first public exhibition, Gropius spoke of a new unity that could arise between art and technology when artists designed attractive yet functional objects for the masses. The aspiration to join artists with industry ended, however, when the Nazis seized power and Bauhaus members dispersed to more hospitable nations.

Merging art with technology wasn't confined to manifestos and pretensions to spark social change. For example, shortly after World War I ended, Thomas Wilfred, a Danish-born artist living in New York City, built his first *clavilux*.[13] The name comes from Latin for "light played by key." Industrial technology of the 1920s helped Wilfred create an increasingly complex and sophisticated array of devices that could project a nearly infinite variety of colored, gently moving light compositions to large audiences. Wilfred's *lumia* reflected developments in modern science, especially visual imagery from astronomy and space exploration. (Similar topics fascinated Marcel Duchamp, who was making his famous piece, *The Large Glass*, also known as *The Bride Stripped Bare by Her Bachelors, Even*, at about the same time Wilfred was building his *lumia*.)[14] Favorable reviews and commercial interest in *clavilux*-like devices for the home followed. After World War II, Wilfred faded from public attention—the new technology of television was a factor—even as several of his large-scale programmed *lumia* compositions were displayed in museum galleries and corporate lobbies. Before Wilfred passed away in 1968, art writers had rediscovered him, situating him as an early pioneer who melded art with electrical technology.

Ambitious and innovative as these efforts were, this early activity failed to establish sustained engagements between engineers and artists nor did the artists' community manage to obtain sufficient patronage from industry or museums. In the 1960s, however, the situation started to change. This time, the impetus came from a multitude of directions as artists, engineers, corporations, universities, publishers, and museums each sought, in their own ways, to splice and solder art and technology together. This plurality of strategies created new technological communities with both engineers and artists as members.

I have deliberately chosen the word "community." It provides my basic unit of analysis, to use a historian's jargon, for several reasons. Where an art movement represents aesthetic tendencies—think of modernism's preference for clean lines, rational design, and geometric shapes—a community is less stylistic than it is sociological. Larger than a lab group or artists' collective, but smaller than a professional society or academic discipline, technological communities have a fluid, interdisciplinary membership that changes over time. Such communities coalesce with varying degrees of formality around particular projects, research questions, or scientific instruments, maintain their cohesion for a time, and then, as often as not, dissipate. Community members bring their own specific sets of skills and knowledge, such that the whole is greater than the sum of the parts.[15] Finally, "community" implies a sense of collective action as well as inclusivity and belonging (and sometimes, of course, ostracism and withdrawal). For many participants in art-and-technology activities, their involvement was personal as well as professional.

In the 1960s, the art-and-technology movement that took form at multiple sites around the world existed in the shadow of that era's other more visible social crusades—those addressing civil rights, the Vietnam War, and the environment—but it shared some similar concerns and goals. It differed, however, from earlier examples of interest in art and technology in several key ways. At a time when the technologies of mass media themselves were changing, public interest and critics' attention were amplified by dozens of well-publicized museum exhibitions and gallery shows. Hundreds of books and articles—from cultural arbiters in New York to flash-in-the-pan newsletters and underground zines—reported on and critiqued the new nexus of art and technology, even as high-profile public relations efforts promoted it. At the same time, artists increasingly began to work outside the "sanctity of the isolated studio."[16] In the 1960s, art became an extension of big business as artists—like engineers—acted not just as creators but as managers of technological processes. Generous financial support from Fortune 500 firms and major cultural institutions helped sustain and enlarge (sometimes to impracticable degrees) this first wave of art and technology. Meanwhile, some corporate managers, informed by psychological concepts, such as Abraham Maslow's "hierarchy of human needs," sought new ways to encourage self-fulfillment among their employees.[17] For the engineers intrigued by such ideas, one path to this was partnerships with artists.

But, more than anything, the desire shared by engineers and artists to *collaborate* distinguished this first wave of art and technology.[18] Sometimes these partnerships were between individuals. In other cases, they involved hundreds of people supported by multimillion-dollar budgets. Compared to pre-1945 examples of art and technology, these alliances coalesced as the result of both top-down initiatives and grassroots-level organizing. In these new social spaces, engineers and artists, as members of professional communities that each changed in profound ways during the 1960s, partnered to make art and also produce a new, hybrid form of creative culture. I should note, given the indiscriminate deployment of the word "creative" by today's life coaches and thought leaders, I suggest something closer to its original meaning: from the Latin, *creare*, to bring forth something new.[19] The people in this book all derived significant satisfaction from making novel and aesthetically pleasing things.

The reasons why engineers and artists wanted to collaborate were complex, personal, and varied. For many artists, it was partly a desire to work with new and often unavailable technologies. Added to this was a sense of crisis about the relevance of commodifiable, object-oriented art made using traditional media in a rapidly changing art world. For engineers—who were facing mounting attacks about their complicity in the arms race, environmental destruction, and other global ills—the art-and-technology movement presented an opportunity to humanize technology and redefine their profession, if only on a personal level.[20] The fallout from these art-technology alliances also had the potential to benefit engineers' employers in the form of commercial products and intellectual property, while simultaneously expanding artists' aesthetic visions and opportunities. The point of collaborations, after all, is for people to create something together that otherwise could not be done alone.

Engaging with engineers opened new creative possibilities for artists. Electrifying the work of art meant experimenting with lasers, digital computers, video devices, miniaturized electronics, and new multimedia environments, technologies all developed during a tumultuous time that saw both the Apollo moon landings and the Vietnam War's escalation. And, like engineers, artists' professional world was changing in significant ways. The emergence of new patrons and cultural brokers coincided with shifting sensibilities about professional identity and methods of art making that went beyond questions of style alone. Taken together, these differences separated 1960s-era artists from their predecessors just a few decades earlier.[21]

International in scope and diverse in methods (remarkably less so in gender and race), advocates of art and technology sometimes expressed broader ambitions that reached toward utopian-seeming ideals. Together, their activities constituted a social movement that was small in scale yet possessed grand ambitions. Collaborations between artists and engineers offered, proponents said, a "revolutionary contemporary sociological process" that might "benefit society as a whole."[22] Advocates for the art-and-technology movement saw their activities transcending the making of art solely for the market, the gallery, or critics' appreciation. Their stated interest in exploring *process*, not making products, comported with broader ways in which artists were redefining the nature of art via minimalism, conceptualism, land art, and other 1960s-era trends. As artist Robert Rauschenberg saw it, spectators who came to art-and-technology shows should be encouraged to watch the setup of technical equipment as much as they would artists' performances. "They should understand," he said, "that we're involved in a process and not in presenting finished products."[23]

These alliances between artists and technologists can be understood as *experiments* in creativity, sociology, and even patronage, which could expand the artists' community and integrate it with industry and university labs. Science experiments and engineering designs often yield results that are imperfect yet still instructive. Advocates saw art-and-technology collaborations as an experiment with how people might engage with technology in a more positive manner while negotiating C. P. Snow's cultural divides.[24] Just as going out and haphazardly observing nature does not constitute a scientific experiment, simply expressing one's emotional inner world on a canvas would no longer do. This new type of collaborative experimentation required rigor, planning, structure, and considerable resources, both technical as well as fiscal.

Many of the art critics, curators, and journalists who responded to the art-and-technology movement, however, stubbornly kept their gaze on the products of artist-engineer collaborations. Here, the view was evaluative, asking if and how an artist was significant or judging a collaboration in terms of aesthetic outcomes, how it fit within a stylistic movement, or whether it pushed boundaries of a particular medium. At the most fundamental level, the question was "Is it art?" I am not concerned with such adjudication. What interests me more is not the art objects themselves—fascinating as they often are—but rather the activities that brought them into existence. This book, in other words, is not evaluative, but explanatory and descriptive. By reading a diverse range of historical sources differently, I instead address the ways in which technologists and artists worked to span divides between their professional communities to make art and also to achieve other goals.

Advocates for closer alignments between art, technology, and science adopted a range of strategies to achieve their ambitions. In Paris, American-born rocket engineer Frank J. Malina initially approached the task by becoming a professional artist. After some experiments in traditional media, he soon gravitated toward making works (like Wilfred, with whom he was often compared) that incorporated motion and electric lights. Working alone, or sometimes with a small cohort of assistants, Malina made scores of "electro-kinetic" paintings and became one of the leading figures of the midcentury kinetic art movement. Then, in 1968, he abruptly changed course and launched a new international journal called, appropriately enough, *Leonardo*. Malina explicitly fashioned *Leonardo* into a venue where artists and scientists could report on their art experiments, describe new techniques, and explore the nature of visual perception.

While Malina, the archetypal professional hybrid, was making art and preparing to launch his publishing experiment, Gyorgy Kepes, a Hungarian-born artist and educator, oversaw the dedication of the Center for Advanced Visual Studies (CAVS) at the Massachusetts Institute of Technology.[25] Kepes had advocated for such a center for years, imagining it as a place where artists, engineers, and scientists could reconcile the values and goals of their professional communities. The artists he selected to be fellows at CAVS would help integrate the visual arts into MIT's curriculum, creating a new generation of technologists familiar with both sides of the two cultures. In an era anxious over the missile gap between superpowers, efforts like CAVS can be seen as an attempt to address cultural gaps in the education of scientists and engineers.

Meanwhile, Johan Wilhelm "Billy" Klüver, a Swedish engineer employed at Bell Labs, was exploring ways to directly connect engineers with artists. At first, like Malina, he started at the personal level, writing essays for art catalogs, helping organize exhibitions, and partnering one-on-one with prominent artists. However, he soon pursued a strategy based on large-scale collaborations and expensive projects. In 1966, he helped establish Experiments in Art and Technology (E.A.T.), a New York-based group that aimed to link technological means with artistic ends to fulfill bigger social aspirations. The organization's large-scale approach mirrored the style of Cold War-era "Big Science" projects, making E.A.T. highly visible, sometimes successful, and—given critics' visceral reactions—often controversial.

The same year E.A.T. switched on its art-and-technology network, Maurice Tuchman, a brash new curator at the Los Angeles County Museum of Art, proposed to put his city on the cultural map. Enticed by the wealth of technological opportunities found in Southern California, Tuchman embarked on an ambitious and lavishly supported program that encouraged the region's high-tech corporations to support art. For five years, Tuchman shepherded an unruly ensemble of artists, engineers, and company managers for his Art and Technology Program, the result of which was a notorious 1971 exhibition.

These new art-and-technology projects (and others like them) burst forth in the 1960s from corporate laboratories, artists' lofts, publishing houses, museum galleries, and university campuses. Bolstered by generous media attention and corporate patronage, the desire to meld two seemingly disparate yet creative cultures was especially prominent in the United States. But fusing engineering with art was not solely an American project. Diverse projects, communities, and exhibitions appeared in the United Kingdom, Europe, Japan, and elsewhere. Taken together, these efforts reshaped public perceptions of both technology and art. This was no slow burn but an aesthetic explosion catalyzed by money, media exposure, and the creative energies of engineers and artists alike. For some participants, it was a short, tumultuous affair. For others, these interactions left indelible marks on the rest of their professional lives.

Then, after barely a decade of highly visible and expensive efforts, this wave of art-and-technology activity retreated. Although this turned out to be only a temporary ebb, art writers judged these attempts to meld art with high technology a failure. Critics attacked interdisciplinary partnerships as an aesthetic disappointment that had somehow polluted the art world. (Of course, such judgments erred wildly in presuming that art had ever been free from such corruption in the first place.) Similarly they castigated artists as amoral opportunists for collaborating with the stewards of the Cold War military-industrial complex. Meanwhile, the economic downturns of the early 1970s quashed the willingness of corporate managers and engineers to risk engaging with artists. By the mid-1970s, the art-and-technology movement appeared as out of vogue as moon landings, supersonic aircraft, and other techno-utopian projects launched in the mid-1960s.

Nonetheless, collaborations between artists, engineers, and scientists created an ad hoc but durable infrastructure that helped support future art-and-technology activities. It also established a model for a new creative culture based less on Snow's bifurcated categories. Even as partnerships and formal organizations slipped into hibernation or dissolved, university programs, publications, and personal interests aided the emergence of subsequent waves of what art writers and museum curators started calling "digital art" or "new media art."[26] By the 1990s, artists could access and experiment with cutting-edge technologies much more easily than their 1960s-era counterparts. But unlike earlier partnerships, which relied on technologies developed for the Cold War by military-industrial institutions, more recent engagements with technology often originate from today's information-entertainment complex as prominent companies such as Microsoft, Facebook, and Apple have helped support the work of hybrid artist-technologists.[27] As a result, many of the older divides between engineers and artists now seem less abyssal as new professional, technoaesthetic communities have begun to coalesce around the continued fusion of art and technology.

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Technology and science are central to understanding the larger historical contours of what scholars have come to call the "long 1960s."[28] In this tumultuous time period, bookended roughly by Sputnik's launch in 1957 and the final Apollo moon landing in 1972, engineers and scientists helped produce the foundations of today's techno-modernity: the personal computer, modern electronics, communications satellites, the internet, biotechnology, to name just a few examples.[29] Artists partnered with engineers even as the race for outer space and its older sibling, the nuclear arms race, influenced geopolitics and popular perceptions of technology. Electronic technologies and electrical engineers were especially critical for the aesthetic experiments carried out during this first wave of art and technology. During the 1960s, modern art literally became electric—wired, connected, soldered, and interfaced to computers, circuits, and cybernetic concepts.

This was also the same time in which, according to sociologists such as Daniel Bell, Western capitalism absorbed and appropriated the radicalism of the avant-garde arts scene. In *The End of Ideology*, first published in 1960, Bell argued that artists' creativity was now a potent ingredient for corporate research and development.[30] As engineers and artists collaborated, parallels began to emerge between artists' inventiveness and engineers' approach to creating new technological products.[31] As companies and economies were boosted by the extraordinary prosperity that marked much of the 1960s, Bell and other scholars predicted that engineers stood on the precipice of an eventual postindustrial society when skills for managing an expanding knowledge economy would take precedence over the traditional manufacturing of things.[32] Process would, the argument went, take precedent over products.

With the Ages of Apollo and Aquarius merging, engineers had a central role as builders and maintainers of complex technological systems that sprawled across the planet. Well-trained, firmly middle-class, and often white, male, and politically conservative, they were among the most plentiful of white-collar workers in Cold War America. In the United States and Europe, engineers were tenders of modern capitalism, providing technological prowess that made the conveniences of modern life possible. But, like artists, engineers were also experiencing profound professional changes while also seeking to demonstrate their relevance to society.

The vital importance of technology in this era presents us with a puzzle when it comes to historical studies of the art made during the 1960s. If one were to leaf through the glossy pages of art history surveys and textbooks (a slow-changing and conservative measure, to be sure), it's almost a foregone conclusion that there will be few if any mentions of the 1960s-era art-and-technology movement. Indeed, it's quite possible to find little to no discussion of technology at all.[33] In these narratives, engineers and scientists are invisible. This lack of attention is puzzling as several artists who populate the canon of modern art history—Rauschenberg, Cage, Duchamp, Warhol, Lichtenstein, Serra, Johns, and many more—worked with engineers at some point. But their experimentation with technology often appears camouflaged in favor of more familiar accomplishments. For the relatively small group of art historians who *have* considered the art-and-technology movement, their attention, unsurprisingly, has largely been on participating artists. This obscures key actors and communities—seemingly mundane engineers and scientists, corporate managers, benefactors, and publishers—to the extent that, until now, a larger and richer story, one that is about technology as well as art, has remained elusive.

One explanation for the absence of technology from most art-oriented histories stems from the prevailing but mistaken belief that a vast majority of Americans and Europeans in the 1960s rejected science and technology en masse. So perhaps it's expected that we would imagine the era's artists to have been likewise opposed. But such an assessment obscures the enthusiasm that many people had for *certain kinds* of technology, even as they rejected the missiles and mainframes of the Cold War era.[34] It was a time of moonwalks as much as Woodstock, after all.

Likewise, historians of modern science and technology have often focused their attention on the expensive, large-scale experiments and the effects of military patronage on knowledge production.[35] As a result, art and artists remain a relatively unexplored topic. Noting these absences of engagement is not meant as a criticism of scholars from either discipline. Rather it's an observation made in the hope of finding more common points of interest between two groups of scholars who often work in isolation from one another. I want to explain the recurring waves of interest and enthusiasm by drawing on ideas, scholarship, and research materials from art history *and* the histories of science and technology. I do this in three ways.

First, I shift focus by giving more attention to artists' underrecognized partners in collaboration: engineers and scientists. Despite their professional credentials and expertise, most contemporary observers relegated engineers to what historian Steven Shapin has called "invisible technicians."[36] This originally referred to the highly skilled craftsmen of the early modern period who helped perform key scientific experiments yet were later erased from histories of science that privileged their employers. Likewise, in his classic sociological study *Art Worlds*, Howard Becker surveyed the oft ignored people—paint makers, insurers, studio assistants, curators—who performed the mundane yet necessary labor that kept the art world working.[37] My understanding of the art world is similarly broad, encompassing more than just the upper echelons of artist stars, celebrity curators, and influential critics.

My aim is to help recover narratives that are more diverse than canonical art histories might suggest by restoring the technologists, who were central to the era's collaborations, to the foreground.[38] This approach helps recapture the experiences of technical experts who contributed time, skills, and, in some cases, aesthetic advice to their artist colleagues. So, in a sense, I'm reading this particular slice of modern art's history against the grain. During the time period covered in this book, the creative process of making artwork transformed. At the same time, the artworks that engineers and artists jointly produced performed a type of work as well, broadcasting a signal that the two communities had interests that imbricated and intersected. Reflecting the historical actors' larger interest in the process of making technology-based art, this becomes an account grounded in gerunds: organizing, writing, publishing, strategizing, funding, programming, wiring, soldering, exhibiting, and critiquing.

Second—again moving against the grain—this book questions the verdict imposed (at the time and sometimes retrospectively) that the art-and-technology movement of the 1960s was a failure. Instead, its ideals and ambitions provided a valuable institutional base for the university and corporate programs that followed. Moreover, even if a particular art-and-technology project didn't fulfill all of its advocates' ambitions, it's important to recapture the enthusiasm, excitement, and uncertainty of what it was like at the time.

This history of what might seem an obscure, long-ago trend in the "prissy" world of artists and curators remains relevant today. Creative collaboration and interdisciplinarity, two goals of the art-and-technology movement, are prized and promoted by corporate leaders and college administrators today. Conferences, journals, and societies devoted to activities at the interfaces between art, science, and technology are again proliferating. Since 2010, national education leaders have lauded the value of adding arts and design to the traditional science, technology, engineering, and math framework (sometimes this is branded as "STEM to STEAM," where the "A" refers to art, or, in other places, "SEAD" for science, engineering, art, and design).

These activities reflect aspirations expressed by art-and-technology advocates fifty years ago. This book, in other words, reveals the deep historical roots of these contemporary efforts. In fact, one of the threads running through my narrative is that the recurring waves of art and technology consistently reflect concerns about how engineering students should be educated and how the arts and humanities might contribute to their sense of social responsibility. For university educators, both fifty years ago and today, the question of how to humanize engineers remains a puzzle to be solved. And all of this debate, of course, reflects and responds to contemporary economic circumstances, from the unparalleled boom years of the long 1960s to the tumult caused by the Great Recession.

To be fair, art and technology was (and remains) just one small room in the expansive, quirky house called the art world. The results of art-and-technology collaborations inhabit their own niche here, found somewhere between the machine shop, the museum, and the market. In the spring of 2019, the big art news was that *Rabbit*, Jeff Koons's three-foot-tall, shiny, stainless steel bauble, had sold at Christie's Auction House for over $91 million, an auction house record. (By time you are holding this book, it's quite probable that this marker of cost, if not of taste, will have been broken yet again.) Despite the role of technology in transforming economies, geopolitics, and cultural consumption, today's digital and new media artworks simply do not command the attention of aesthetes and the affluent in the same manner as the sale of a David Hockney painting.

Finally, I see this book as an experiment of sorts in writing about the history of art and art making. It imports some perspectives and ideas from the histories of science and technology into a less familiar territory. This terrain has been surveyed and marked largely by academics and curators who write about modern art and new media. (As one can imagine, calling a particular media "new" while also writing about its history suggests something of a moving target.) Obviously, historians of science and technology know a good deal about topics such as creating research programs, evaluating the importance of experiments, and interpreting results as successes or failures. One lesson these histories impart is that we should do more than focus only on the (lucky) few people who made important discoveries or developed important inventions. Although quite a few of them populate this book, my attention likewise is not given only to artists deemed famous today.

As this book engages with the comingling of art, technology, and science, my narratives address topics familiar to historians of technology and science. These include the enthusiasm for and reaction against large-scale research collaborations, the prevailing political economy and institutional infrastructure that supported them, and the pursuit and effects of publicity and publishing on knowledge production. Engineers were *essential* participants in 1960s-era Big Science, and the same can be said for the Big Art spectacles of the same era. Art, to paraphrase Claude Lévi-Strauss, is good for historians to think with.

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As this book addresses both art and technology—ludicrously broad topics even if one stays within the narrow confines of the past half century—something needs to be said about the examples I've chosen as well as some distinctions I've relied on. These break down to questions of *signal*, *sampling*, and *static*.

I have been drawn most strongly to formal efforts like Experiments in Art and Technology and *Leonardo* as opposed to the many one-on-one efforts that dot this period. I'll borrow an electrical engineering term ("signal strength") as justification. Compared to artists and those who write about them, engineers often appear as relatively silent actors in the larger historical record. Moreover, compared with scientists, engineers are papyrophobic.[39] That is to say, they are less inclined to record their recollections and activities on paper. Compared to scientists, far fewer engineers write memoirs. But a strong signal from the many engineers who participated in the art-and-technology movement can be detected from the large, institutionally supported, well-publicized, and formal efforts. For example, the Getty Research Institute in Los Angeles has over 230 archival boxes and thousands of illustrations that collectively preserve the history of E.A.T. Among these hundreds of thousands of pages are letters and reports written by engineers who collaborated with artists. Well-documented efforts like these offer the best means of recovering signals—about engineers' perspectives, motivations, and experiences—from the noise.

Writing about the history of anyone or anything necessarily involves sampling. Many artworks resulting from these collaborations are best described using a term from the era. When British artist Dick Higgins coined the word "intermedia" in 1965, he was referring to art that "seems to fall between media." Intermedia art was understood as a hybrid thing, cross-fertilizing and blurring boundaries between traditional arts like painting, sculpture, and dance while adding film images, electronic sounds, and other technologies.[40] Higgins's term suggested a coming era when traditional borders between artistic media as well as academic disciplines and professional communities would shift and possibly be erased. The intermedia pieces engineers and artists created were, in effect, multisensory, interactive, aesthetic environments that broke down barriers between high art and its popular, commercial counterparts and, quite often, directly involved the audience.[41] However, my sampling means that not all media (electronic music, for example, presents its own fascinating but vast topic) receive as much attention as I have paid to arts that are primarily visual in nature.

Finally, there is the issue of static—what engineers colloquially call the distortions when radio or television transmissions became fuzzy or ambiguous. The metaphor of static can also be applied to overly categorical definitions of art, technology, and science (and their practitioners). Journalists sometimes labeled people like Billy Klüver and Frank Malina as scientists who built things. In other cases, they appeared as engineers who did scientific research. The differences between science, engineering, and technology might seem to be just academic semantics. But they *are* indeed quite different sets of activities. The knowledge and skills required to do electrical engineering are not the same as what a botanist or astrophysicist needs. And, although engineers and artists were understood as inhabiting two very different worlds, both communities based their professional success on how well they manipulated the physical world to make new things, something which often set them apart from scientists. As one scholar has framed it, scientists discover things whereas engineers (and artists) make things.[42]

Nonetheless, when it came to making comparisons and drawing boundaries in the 1960s, the established point of reference for art critics was typically the binary between art and science, not art and technology. Such conflations (and sometimes confusions) continue to persist today as art is paired interchangeably and randomly with both science *and* technology. One writer has used the term “artsci” to describe a multitude of “colliding worlds,” despite the fact that many of his examples are based on engineering, not science. Meanwhile, “artscience” and, more recently, “sciart” are pitched as a lab-based activity where different types of creativity come together.[43]

I don’t think there is an easy way to eliminate the static that can blur our view of these categorical boundaries. I also don’t think this is necessarily a bad thing. Often times, the historical actors in this book, unconsciously or not, made distinctions between art, science, and technology for reasons that made sense to them at the time. Each offers a regime where aesthetics, discovery, knowledge making, and creativity are important and, likewise, each serves as a historical category in its own right. So, rather than try to impose some pedantic demarcation, I instead accept my actors’ terms and follow their own occasional confusion as to the differences.

My personal interest in the art-and-technology nexus was first stirred by what I saw where I work—an office on the humanities side of campus. The engineers and scientists are on the other side, their bounty of ocean views suggesting how deeply C. P. Snow's claims of a bifurcated academic culture are baked into university architectures. But I routinely walk past a building where students and faculty create objects and installations that combine the visual arts and music with engineering. My school started its Media Arts and Technology Graduate Program more than two decades ago. Scores of universities around the globe have invested in similar programs, which are often explicitly presented to alumni and donors as valuable conduits across academic disciplines or as pathways to fostering innovation.[44] So I started this project with a historian's most basic question—*Why did that happen?*

My interest in the question of creative practices pulled me in further. I started my own career as a scientist before becoming a historian. I know how scientists do research and how historians write books. But I knew next to nothing about how artists make art. The historical contingencies and circumstances that brought engineers and artists together in the 1960s galvanized my enthusiasm further. And, as I looked closer, I started to picture how the confluence of art and technology produced waves that surged at various times and then diminished. These bursts of activity created ripples, sometimes even speculative bubbles, which then shaped the form of subsequent waves. At the same time, the participants in each new wave would often loop back to the past to find examples and justifications for their interdisciplinary activities and advocacy.

Looking at successive waves of enthusiasm for melding art with technology over the past half century reveals the shifting relationship between the worlds of culture, research, and business, as well as audiences' expectations and reactions. At its essence, this book finds that the borders of two important cultural realms—art and technology—are anything but separate, fixed, or immutable. As Natalie Jeremijenko's *Live Wire* suggests, art can be technology and vice versa, complicating categorizations and boundaries. The question lies not in the ways in which art and technology are different, but in the times, places, and spaces where these dynamic enterprises intersected. This common ground was generative, yielding surprises, and sometimes proving unstable. Likewise, we see professional identities of artists and engineers as evolving and flexible. By engaging with one another, artists and technologists have repeatedly built new creative communities in which participants can exhibit imagination, inventiveness, and expertise. And, in the process, they electrified both artworks and the work of making art.

1

PREAMPLIFIER

> It is bizarre how very little of twentieth-century science has been assimilated into twentieth-century art.[1]
>
> C. P. Snow, 1959

In February 1953, when Frank Malina sat down to write his parents, there were many things he could have told them. The American-born rocket engineer could have mentioned the frustration he felt because the US State Department—acting on evidence the FBI had collected after more than a decade of surveillance—refused to renew his passport. Or the forty-one-year-old research engineer might have lamented how the American government's harassment had provoked his resignation as the scientific director of a United Nations-sponsored humanitarian organization. Maybe he could have written about his fears that the rocket technologies he helped invent were launching the Cold War arms race into dangerous new territory. But Frank Malina discussed none of this in the letter he mailed off to his hometown in rural Texas. Instead, he announced that he was going to become an artist.[2]

For more than two decades, Malina's parents received letters charting their son's transition from a young engineering student to one of the world's premier experts in rocketry. During World War II, Malina oversaw the transformation of his research and designs into military hardware. When that conflict ended, Malina, discomfited by growing tensions between the United States and the Soviet Union, left rocketry research behind. He could already envision future machines that would carry nuclear bombs from one continent to another. Deeply opposed to this, he instead moved to Paris and took a position at the United Nations Educational, Scientific and Cultural Organization (UNESCO) where he promoted international scientific cooperation.

Malina announced his new career path with the same mixture of circumspection and self-deprecation found in most of the letters his family received. Underneath his nonchalance, however, lurked pressing anxieties, not the least of which were legal and financial. Yet, over the next decade and a half, Malina transformed himself into a professional artist whose specialty was blending traditional painterly techniques with motors and electrical components to create complex “electro-kinetic paintings.” Compared to the large and often well-funded collaborations that came later, Malina typically worked alone. This approach began to change when he launched *Leonardo*. The former rocketeer would draw on an impressively large network of personal and professional contacts to get each issue of the journal out the door and into print. Meanwhile, his ideas for unifying art, engineering, and science—an interest he had nurtured since the 1930s—would be echoed and amplified by the broader art-and-technology movement.

AN AMERICAN ROCKETEER IN PARIS

The National Air and Space Museum in Washington, DC serves as something of a secular shrine for spaceflight enthusiasts. Like any religion, the church of spaceflight has its saints, sinners, and heretics. Walking around the museum, one finds artifacts, for example, that acknowledge the research of rocket pioneer Robert Goddard. NASA has two research centers named after him but the scientist never sent a rocket much higher than a few miles. Other displays laud the contributions of Wernher von Braun. His V-2 missiles killed thousands of civilians during World War II. Thousands more perished, conscripted as slave laborers, while building the weapons. During the Cold War, Americans overlooked, forgave, or ignored the former Nazi officer’s sins as von Braun’s engineering and management expertise helped the United States beat the Soviets to the moon.

Frank Malina’s contributions to spaceflight can also be found at the museum, but they are not as visible. Immediately after World War II, this outcome might have surprised some experts. Malina’s vision and engineering acumen had enabled the United States to successfully launch a series of rockets that were tools of science, not of war. Magazine articles and newspaper stories noted his accomplishments and the organizations he helped create. But, like a missile disappearing from view, Malina himself soon vanished from the world of practical rocketry and, almost, from histories of space exploration. To understand why Frank Malina was not hailed then (or now) as America's foremost rocketeer—and why he decided to become an artist—arcs us back to when he became renowned for, and then relinquished, building rockets. These experiences would later influence and affect his approach to making art.[3]

Born in October 1912, Frank Joseph Malina spent his early childhood in Brenham, Texas northwest of Houston. But his parents were both professional musicians with strong ties to Czechoslovakia and, for five years, Malina and his family relocated to what was then the Austrian province of Moravia, before returning to Texas. While living overseas, Malina read—in Czech—Jules Verne's classic science fiction book *Voyage to the Moon*, an experience that ignited his lifelong interest in space exploration. But, compared to other dreamers of space travel, like Robert Goddard or Wernher von Braun, Malina's enthusiasm for space was not an obsession to be pursued at any personal or moral cost.

Malina's parents, especially his strong-willed father, pushed him toward a career in music. Instead, in 1930, Malina, who rarely lacked in self-confidence, left Brenham for Texas Agricultural and Mechanical College where he studied mechanical engineering. After graduating in 1933, Malina migrated westward to Pasadena to begin graduate studies in aeronautics at the California Institute of Technology. A photo taken around the time he started at Caltech shows him as a slim and handsome man—five foot eight and 130 pounds with dark features and, according to his FBI file, a small scar on his chin—staring confidently at the camera.

By the 1930s, Caltech stood at the forefront of aeronautical research. Two major acquisitions galvanized the school's rise to world prominence in this field. In 1926, mining magnate and philanthropist Daniel Guggenheim donated $2.5 million to build a new laboratory and wind tunnel. These funds also attracted the Hungarian research engineer Theodore von Kármán to Caltech as the director of the Daniel Guggenheim Aeronautical Laboratory.[4] Malina, who came to view von Kármán as a second father, absorbed his mentor's goal of making aeronautics as rigorous as possible by placing it on a foundation of basic scientific theory. Like his mentor, Malina looked to make bridges between science and engineering just as, later in life, he worked to join the worlds of art and science.

In March 1935, when one of von Kármán's students reviewed the hypothetical possibilities of using rockets for propulsion, Malina was already primed to the notion. He hinted about having "other ideas" besides his work on propeller-powered craft

Figure 1.1 Frank Malina as a graduate student at Caltech. Image courtesy the Malina Family Archive.

and told his parents not to be surprised “if I get my fingers mixed into rocket propulsion.”[5] With support from von Kármán, Malina convinced naysayers at Caltech to let him to switch his doctoral research to the study of rockets. This was risky for Malina, both careerwise and personally, given the propensity of early rockets to explode. The Great Depression’s effects were still severe and a safer bet for Malina would have been to get a job in the local aircraft industry.

Malina was courting other risks as well. Throughout the 1930s, Malina’s letters home were filled with his frustration at American capitalism. Buried in files he kept until his death was a term paper for a philosophy class at Caltech titled “Can an Economic System Based on the Profit Motive be Ethical?”[6] (His answer, not surprisingly, was “No.”) He soon started spending time with other like-minded faculty and students at Caltech. In November 1938, he joined Professional Unit 122 of the Pasadena Communist Party, taking the pseudonym Frank Parma.[7] Some members were hard-core socialists while others were liberal-leaning persons interested less in radical political revolution than advancing causes such as civil rights. Malina was much more inclined to view science and technology, not politics, as the best forces for instigating social change. But, regardless of his intent or consistency of interest, Malina's involvement with Unit 122 soon placed him in serious legal jeopardy. Starting in 1938, the Los Angeles Police Department began monitoring him and, four years later, the FBI initiated its own surveillance. The most recent version, still heavily redacted, of Malina's FBI file, in fact, shows that the Bureau watched him until 1973, a period of almost half his life.[8]

Malina's interests extended well beyond engineering and politics. We know this because Malina, curiously diligent in documenting his personal history, dutifully recorded what he read in his "Book of Life." Novels such as Sinclair Lewis's *Arrowsmith*—its plot featured a young, progressive-minded scientist confronting marital and moral challenges—are interspersed with tomes on Continental philosophy, socialism, psychology, political theory, and the history of science.

Art and music were also strong attractors for the young engineering student. A piece of paper tucked away in his correspondence has him citing the French polymath Henri Poincaré and his writings about the subconscious mind and creativity. "Art cannot be created from a vacuum," Malina scribbled, "it is at best an extrapolation of the known objective world under a new form of expression." Great art, Malina continued, could not be created "without technique or with technique alone." Artistic talent, like creativity in engineering or scientific research, was "an expression of a mind that has spent a great deal more time on a certain field than other minds."[9] Throughout the next several decades, the nature of creativity remained a serious interest for Malina. In 1953, when a Paris gallery invited Malina for his first solo show, he ventured that "creativeness in art does not appear . . . to differ in kind from creativeness in science or any other human activity."[10] It was almost as if he was still ruminating over ideas he had jotted down fifteen years earlier.

Another factor in Malina's growing curiosity about art was his relationship with a Liljan Darcourt. They married in June 1939, the same year Darcourt, then just eighteen years old, started classes at the Otis Art Institute. Soon, more art-related titles started appearing in Malina's "Book of Life." From the start, however, their marriage was complicated. Much of his time in Pasadena was spent doggedly working in the lab to finish his degree while frequent trips (once the war started, these sometimes extended for weeks) took a considerable toll on their relationship. Soon after they married, Malina, eager for extra income, spent weeks at the drafting board producing technical illustrations for an engineering textbook von Kármán was working

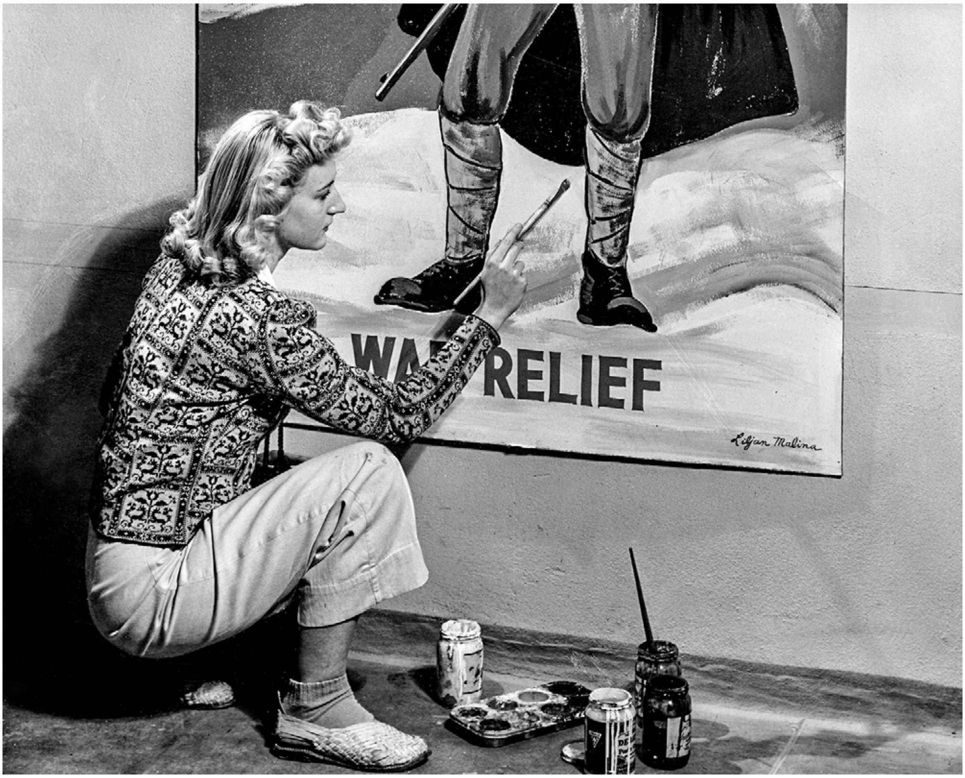

Figure 1.2 Liljan Malina working on a poster in support of the Russian war effort, 1942. Image courtesy the Malina Family Archive.

on. Even as he admired Liljan's paintings, done in an abstract, nonfigurative style, Malina asked, "Do I see in you the achievement of my suppressed ambitions?"[11]

Throughout the late 1930s, Malina's rocket-related research continued to develop and a small group of graduate students and enthusiasts coalesced around him. On Halloween in 1936, the rocket group tested a prototype liquid-fueled engine in a dry riverbed above the Rose Bowl on the outskirts of Pasadena. Soon after this, von Kármán helped the team secure some lab space at Caltech. Some months later, Malina briefed the National Academy of Sciences on the utility of rockets as a means to help propel aircraft and boost their speed. With the political situation in Europe deteriorating, government money became available to support his group's work. An initial grant of $1,000 marked the start of what was, by the war's end, a flood of money—millions of dollars—that flowed to Caltech for rocket research.

Perfecting these jet-assisted takeoff (JATO) rocket engines, attached to the underside of wings, meant mastering the dark art of solid rocket propellants. The first JATO units made by Malina's team, which included the self-taught chemist and occultist Jack Parsons, were successfully tested in August 1941. By this time, Malina had received his PhD and joined Caltech as an assistant professor. He oversaw the rocket group's permanent return to the dry arroyo outside Pasadena. Corrugated iron shacks and cobbled-together testing equipment became the seeds for what today is NASA's Jet Propulsion Laboratory, an organization Malina helped found in 1943 and then later directed. ("Jet" was chosen purposely over "rocket," which in the 1940s remained a disreputable term more aligned with science fiction stories.)

Building rocket prototypes was one thing. But the military wanted the JATOs to be mass produced for use in the field, a task which Caltech was not inclined to do. Von Kármán tried to interest local companies but found no success. So, in March 1942, he, Malina, and a few other rocketeers contributed $200 each to start a company called Aerojet and assigned their patents to it. In just six years, Malina had helped show that rockets were not only possible and practical but also profitable.

By the war's end, Caltech's rocket program had grown from a handful of curious students to several hundred workers. When the military requested something equivalent to the Nazis' V-2, Malina suggested an intermediate step—a sounding rocket that would carry not explosives, but scientific instruments. On October 11, 1945, Malina watched as a WAC Corporal rocket was placed in a launch tower at White Sands Proving Ground. It was a slight thing, only sixteen feet long, a foot in diameter, and weighing less than 300 pounds before fueling. After the rocket burst upward, radar tracked as it climbed over forty miles into the blue New Mexico sky, more than twice the height Malina had promised the military and the highest any American rocket had yet gone. Subsequent launches in 1946 and 1947 marked the apogee of Malina's career as a rocketeer, a period of time when he was *the* foremost American authority on the subject.

Frank and Liljan tried to maintain their marriage via letters, his typically posted from distant cities where he was supervising rocket-related activities. He described, for example, the museum and gallery exhibitions he visited in New York and Washington in between Pentagon meetings. In October 1944, just before departing for a multiweek tour of German rocket sites in Europe, Malina "dropped into a museum that shows non-objective art." (This was probably the forerunner of today's Guggenheim Museum, a nice symmetry given the financial support the Guggenheim family had indirectly given to Malina's aeronautics research.) He liked "the color

Figure 1.3 Frank Malina in October 1945 with the WAC Corporal sounding rocket, White Sands Proving Ground. Image courtesy the Archives, California Institute of Technology.

and geometrical arrangement of the pictures"—the collection had works by artists such as Wassily Kandinsky—but found explanations the museum's "adherents" were "dishing out" to be a "little too thick." It wouldn't be the last time that Malina expressed antipathy toward interpreters and critics of art. Nonetheless, he told Liljan not to be surprised if he borrowed her easel and started "making non-objective pictures" of his own.[12]

While in New York, Malina became friends with Alvin Lustig, a graphic designer who later achieved considerable acclaim for his typefaces and book jackets, which became icons of midcentury modernism. Malina and Lustig had long discussions about art and creativity, conversations that continued when the designer relocated to Los Angeles. Malina, who never shied away from debate, noted how he and Lustig were "struggling with the basic ideas of art and science" before finding some "common ground for both activities." As Malina described it to Liljan, this common ground centered on "the individual judgment of 'inherent rightness' for pioneering steps taken in the direction of undiscovered reality." In art as well as science, breaking new creative ground, they concluded, required courage, which came primarily from a sense of intuition honed by experience.[13]

While Lustig and Malina debated philosophy, Liljan was moving to New York City. She eventually found success as an artist, employing a style that became increasingly abstract. Letters between them from this period contain a jumble of prosaic details mixed with raw emotional confessions and insights gleaned from the psychotherapy sessions each was attending. Despite attempts to reconcile, the two of them filed for divorce in 1946. Malina tried to maintain a positive attitude about his situation with Liljan but, when it came to world politics, he often sounded dispirited. "Too many people," he lamented, "are getting ready for World War Three."[14]

Something with far more immediate implications added to Malina's personal turmoil. In September 1945, government agents raided Frank and Liljan's house in Pasadena looking for incriminating materials. Malina had already destroyed some documents and dumped the rest into cardboard containers that Liljan hastily ferried away.[15] Nonetheless, the agents questioned Malina and ransacked their house. If Malina had suspected the American government was watching him, he now had proof. Malina decided to take advantage of Caltech's willingness to grant him a leave of absence. "I was mentally and physically exhausted," the reluctant rocketeer wrote, "and determined to make a serious appraisal of myself and my hopes for the future."[16] But, given the clouds of suspicion gathering around Malina, this was a future perhaps best not pursued in the United States.

In 1947, Malina—now divorced—moved to Paris and took a position as scientific director at the newly formed United Nations Educational, Scientific and Cultural Organization. UNESCO's corps of experts wanted to promote science and technology as an instrument for improving the material conditions of people around the world and reducing economic and industrial inequality so that future conflicts might prove less tempting.[17] Malina's six-year tenure at UNESCO was not simply a transition from making rockets to making art, however. Instead, it exposed him to a set of ideas and a new social network that later informed his work as an artist and as the publisher of *Leonardo*.

When Malina joined UNESCO, British biologist and eugenicist Julian Huxley was directing the fledgling organization. In Huxley's estimation, UNESCO's overall philosophy should be based on a guiding principle of "scientific humanism," a perspective Malina also came to profess.[18] The term originated in the interwar period with the Belgian-born historian of science, George Sarton, referring to a new culture based upon "humanized sciences." Writing a quarter-century before C. P. Snow's critique of the "two cultures," Sarton claimed that gaps between sciences and the humanities could eventually be spanned via improvements in education.[19]

Huxley was keen to find common ground between science and art but also to delineate their differences. Science and art were essential, Huxley claimed, not just for their inherent value—the increase of knowledge or the creation of aesthetically pleasing works—but also for their utilitarian possibilities. The "practical application of creative knowledge and art" involved "translating theory into practice." Just as science was fundamentally about the "pursuit and application of organized knowledge," so the creative arts "must arouse the aesthetic emotion" and generate an "impact, [which has] something almost physiological about it."[20] In the years to come, Malina often wondered *why* people responded to particular artworks and believed the topic was open to scientific study.[21]

Even as Malina was settling in Paris, the nascent Cold War was diminishing Americans' enthusiasm for internationalism. The FBI monitored Malina after his move to Paris and his security file continued to grow. Soon, these reams of now heavily redacted pages noted a major change in his personal life. In 1948, he began seeing Marjorie Duckworth, a young British woman who had studied sociology before taking a job at UNESCO. They married in 1949 and soon had two children, Roger and Alan. Their modest home gradually became the site of regular evening gatherings populated by well-educated people from the eclectic UNESCO community.

Malina's FBI file transports the reader into a world where malevolence and absurdity meet. In one photo, his face and beard are lit in such a manner that he assumes a Lucifer-like appearance. His name is misspelled in some reports. Evidence that might have been central to Malina's prosecution for "fraud against the government" went missing or was misfiled. Nonetheless, the noose continued to tighten. By the spring of 1951, UNESCO had promoted Malina to director of the entire Division of Scientific Research. But when he attempted to renew his passport—the job required extensive travel—the request was denied and Malina was warned that further travel by him "would be contrary to the best interests of the United States." Without a passport, Malina was suddenly marooned in France.

His situation was even more precarious than he realized. In late 1952, the FBI pressured the Department of Justice to issue a sealed indictment against Malina for making false statements to the government—he allegedly had not listed prior membership in the Communist Party when filling out his Personnel Security Questionnaire and had answered "no" when asked if he had ever belonged to any groups that wanted to overthrow the US government—and a secret warrant was issued for his arrest should he return to the United States. Malina was officially declared a fugitive with bond set at $10,000. The State Department pressured UNESCO to transfer Malina back to the United States where he could be detained. The FBI expanded its questioning and UNESCO, bowing under the pressure, restricted his work activities on the grounds that he posed a security risk.[22] Unable to leave France, Malina, now with a family to support, faced the possibility of losing his job as well.

The circumstances in which Malina found himself were ironic to the point of being farcical. The Cold War had spurred the growth of Aerojet, the company Malina helped start years earlier. During the 1950s, Aerojet's rocket motors powered a whole family of vehicles including, as Malina had feared, nuclear-tipped intercontinental ballistic missiles. Unlike Aerojet's other cofounders, Malina had retained his Aerojet stock and this had soared in value. Starting around January 1953, a flurry of letters and telegrams went from Malina—a man who had once written a college essay on the evils of capitalism—to his lawyer asking about Aerojet's stock prices.[23] In February 1953, estimating his shares to be worth at least a half-million dollars (close to $5 million today) Malina quit UNESCO.

Now independently wealthy, Malina announced his intention to explore what he called the "art business."[24] In less than a year, the FBI's dossier noted that Malina had already found "considerable success as a painter" by using "new techniques."[25] An informant even provided the FBI with a brochure from his first solo show in Paris.

More than a decade earlier, Malina had entered the military-industrial complex as an engineer committed to research. He emerged from it, unexpectedly, as an aspiring professional artist. What remained unchanged was his devotion to experimentation.

PUTTING ART IN MOTION

To develop new techniques as a professional artist, Malina carried out careful research, first with traditional materials and then with increasingly complex electromechanical systems. This eventually gave him a deep reservoir of experience and tacit knowledge to draw on. From the outset, Malina wanted to break away from traditional subject matter. As he later said, the "vast quantity . . . of nudes, flowers, landscapes, and dead fish" he saw in museums and galleries left him unmoved.[26] Although he painted and sketched his share of landscapes and posed people, Malina was more attentive to finding inspiration in topics like aeronautics, space exploration, biology, and astronomy. Malina wanted his art to communicate personal interpretations of the natural phenomena that modern technologies of scientific investigation—rockets, telescopes, microscopes—made visible.

By the time Malina had decided to play what he sometimes derisively called the "art game," modern art's center of gravity had undoubtedly shifted from Paris to New York.[27] There, abstract expressionist painters and the critics who championed the New York School were creating the first internationally significant avant-garde movement to develop in the United States. Besides making many Americans aware, perhaps for the first time, that there was such a thing as modern art, artists such as Jackson Pollock and Willem de Kooning first became celebrities and then later stereotypes of the lone, heroic artist projecting their feelings and psychological states onto a canvas.

Malina, of course, could not leave France to see firsthand what was happening in New York's art scene (or any other place, for that matter). So works shown in Parisian galleries and museums took on especial import. In the early 1950s, a different style of abstract painting was in vogue in Paris. Sometimes described as "lyrical abstraction" (i.e., *abstraction lyrique*, which was an umbrella term for such movements as *art informel* and *tachisme*), it was spontaneous, like its American parallel, but smaller in scale and less raw in its execution and appearance than, say, a work made by dripping and pouring paint. Artists such as Paris-based Pierre Soulages used careful brush handling to create expressive splashes and their broad, sometimes superimposed, strokes of intense color incorporated cubist aspects. The subjects often depicted by *tachiste* artists, however, continued to draw on traditional landscape and figurative material.

When Malina landed his first solo show in Paris, only eight months after quitting UNESCO, he revealed in the gallery's brochure that color had always "strongly affected" him. At the same time, he noted how "lines, as used in engineering drawing, strongly permeate my being."[28] All that time making technical sketches for von Kármán had left an impression. This predilection for color and linearity set the stage for his first phase of artistic experimentation. In May 1953, Malina noted that he had been "working about 12 hours a day on something that may be a type of picture that has not been exploited before."[29] Interested in the problem of showing relief, depth, and structure, he started to experiment with painted string and wire. Stretched to form straight lines and attached to the picture frame, the lines could be layered and placed on top of one another or against a painted background. He made about two dozen such works, with some titles evoking traditional subjects (*Female Torso*, a landscape series, and yes, *Fish*) familiar to *tachistes*. But others, such as *Rocket Motor* and *Shock Waves*, circled back to Malina's research interests. "To do something new in this art business is not easy," he noted and he remained eager to make his mark in the Paris art scene through some sort of novel and nontraditional technique.[30]

Malina convinced a gallery owner to exhibit his string and wire works, along with earlier painted pieces. His first one-person show opened in late October at the Galerie Henri Tronche in Paris's 8th Arrondissement. Most of the works Malina selected were based on scientific or engineering subjects. "Since few people know anything about science," he wrote, "they find most of the pictures a puzzle. I think it is about time more painters tried to paint subjects which are important today, even if they are difficult." Art critics who saw the show highlighted the novelty of Malina's approach as well as his unconventional career path. "We are astonished and then converted," wrote one critic, claiming Malina expressed "the underlying spirit of our time in a new language." Others were less charitable, noting that Malina's still-developing talents diminished the novelty of his visual experiments.[31]

Malina continued his investigations by adding painted metal mesh to his compositions. He soon realized that the combination of paint and wire mesh could create striking optical effects. For instance, when there are two superimposed wire grids the human eye may sense what are called moiré effects, which give the illusion of movement.[32] These kinds of optical configurations, which Malina started experimenting with in early 1954, later became part of the op art style. These works also marked

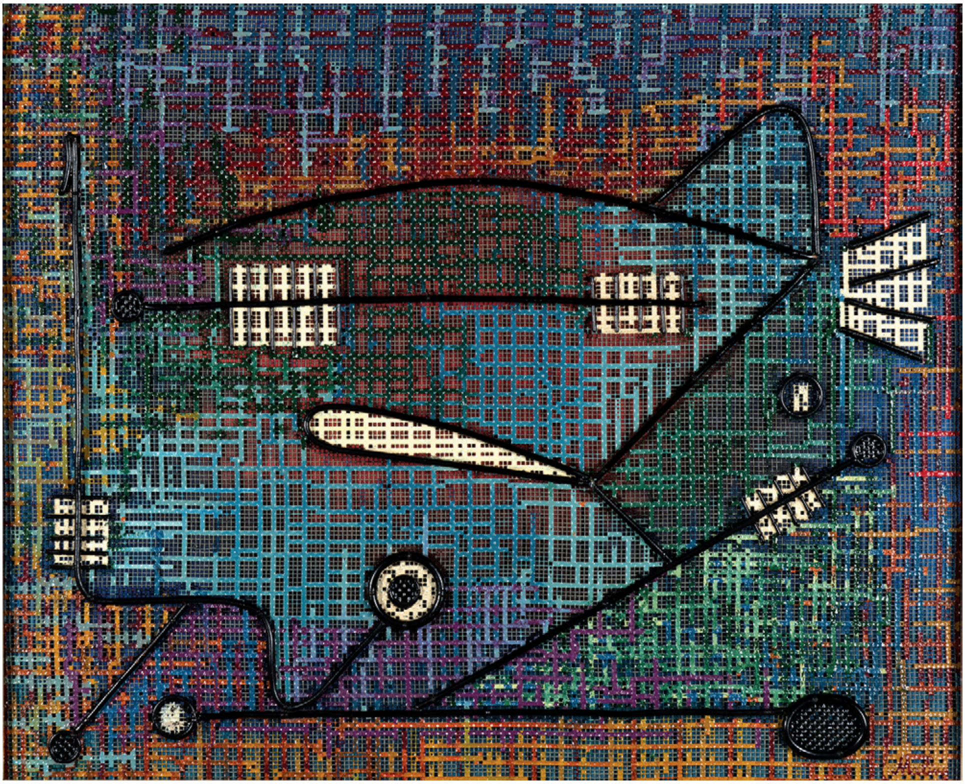

Figure 1.4 Malina's 1953 wire mesh picture *Jet Plane*. Image courtesy the Malina Family Archive.

Malina's initial foray into experimenting with human perception, a topic that would increasingly interest him, especially after he started *Leonardo*.

Malina's first work exploiting moiré patterns was a small piece, roughly a square foot in size, called *Moving Field of Lines* that referenced the electromagnetic concepts of scientists such as Michael Faraday and James Clerk Maxwell. For his next solo show, at the Galerie Arnaud in June 1954, he made a larger piece titled *Deep Shadows*, which depicted a modernist array of dark and light rectilinear shapes. Although he disliked the formal term "abstract art"—Malina insisted all art was an abstraction of something seen or imagined, and preferred the term "non-figurative" instead—he mused that "these abstract things are of use to an artist from a technical point of view, the way mathematics is to an engineer."[33] Just as equations and formulas allowed the research engineer to determine what was possible, Malina believed his art offered a potential tool to probe viewers' perception and possibly improve artists' techniques.

As an engineer, Malina had worked in a world where experimentation in the pursuit of novelty was expected. Now an artist, he expressed consternation that his new line of research had yet to produce anything especially significant. Malina soon became dissatisfied with the visual effects his moiré experiments produced. Eager to increase the contrast, Malina tried placing an electric light behind the layers of wire mesh. For him, the result was tremendous. "[I] saw a new world," he told one art writer, and experienced the "ecstasy that one experiences when making a personal discovery."[34] Malina later explained that he was already primed for discovery by relief images of electric lamps he constructed out of painted wire and wire mesh. Placing an actual light bulb behind the mesh came as a logical extension of this thinking.

At this point, Malina briefly stopped thinking like a researcher who had spent years in labs. "My engineering training should have led me to make a search of the literature on the use of electric light," he later wrote, "but I did nothing of the sort." Instead, following the "common practice of artists," Malina "blundered ahead" to "repeat the errors" and "miss the contributions" other artists had made.[35] Malina's first experiments were unimpressive. Initially, he installed a fifty-watt bulb behind one of his constructions, only to watch a column of smoke rise from the charred wood. Later, while looking at the family Christmas tree, he realized—"how stupid I had been!"—that he could achieve the same optical effects using low wattage bulbs. For his next pieces, Malina stretched layers of metal mesh inside a wooden frame. Sometimes he painted designs on the mesh or inserted colored cellophane. He then attached small bulbs at the back so the light passed through the mesh to the viewer, creating a sense of virtual movement. In 1955, Malina eventually made more than thirty of what he called "electro-paintings."

Malina was not alone in thinking about how he might incorporate electronics in a painterly fashion into his art-making practice. In 1951, for example, Ralph K. Potter, an acoustical engineer working at Bell Telephone Laboratories, published an essay titled "New Scientific Tools for the Arts." These tools included "ways to paint electrically on television type screens" and the "development of an instrument with which the artist may produce vocal music synthetically."[36] Eventually, many of the techniques Potter predicted were taken up by artists in the 1960s and 1970s, including several people associated with engineers from Bell Labs whose work would later be branded as "intermedia" or "new media." However prescient Potter might have been, it's unlikely Malina saw the article, published as it was in a relatively obscure American journal devoted to aesthetics and art criticism, areas Malina had little patience for.

Up to this point, it's difficult to discern what direct effect other artists active in Paris had on Malina's work. Based on his own statements, much of what he was doing was a reaction against artists' traditional subject matter while also reflecting his determination to do something original in terms of technique. A major new show in Paris, however, gave Malina the opportunity to situate his artistic experiments within a larger emerging movement.

Denise René first opened her art gallery, located a block off the Champs-Élysées near the Arc de Triomphe, soon after the Allies liberated Paris in 1944.[37] By 1950, it had matured into a showplace for artists working outside the French *tachiste* style. René, for instance, promoted a form of geometric abstraction called *art construit*. One of her first major clients was Victor Vasarely. In the late 1940s, the Hungarian-French graphic designer's work featured abstract geometric shapes that, although limited to two-dimensional space, conveyed a sense of movement. In April 1955, René presented a group show called "Le Mouvement" that would highlight Vasarely's work along with a small selection of artists such as Jean Tinguely and Jesús Rafael Soto. To add some historical comparison, René and her colleagues included works by Marcel Duchamp and mobiles by Alexander Calder.

While movement was the theme, there was little consistency in the techniques used by the artists in René's show. While Vasarely relied on optical tricks, Calder, Duchamp, and Tinguely used wind or mechanics to make their pieces actually move. Other artists even presented pieces where the spectator could manipulate the object and, in the process, help create the artwork. Despite, or perhaps because of, this diversity, "Le Mouvement" showcased kinetic art as an emerging new stylistic movement. For years after René's Paris show, kinetic art shows proved enormously popular and commercially successful in Europe and the United States. Although "Le Mouvement" did not include any works by Malina, a chronology prepared for the show included him in a list of artists who had recently "introduced the concept of movement" into their art.

Works displayed at René's gallery presented Malina with the diverse array of techniques and approaches to conveying movement. In the trajectory of Malina's art career, "Le Mouvement" marked something of a turning point. Eager, even anxious, to invent something artistically novel and significant, he stopped making pieces that simply offered a visual impression of movement. Instead, he decided to integrate actual physical movement along with changing light and color. Besides providing him with the personal sense of discovery he wanted, Malina's new approach would establish his international reputation as a kinetic artist.

ENGINEER AS ARTIST, ARTIST AS ENGINEER

Malina leapt into a new round of experimentation even before the "Le Mouvement" show ended. He initially placed low-wattage lights behind layers of colored mesh as he had done before but added a new element: switches called thermal interrupters that periodically and randomly turned the lights on and off. The flashing and blinking lights converted his static moiré images into electro-kinetic paintings. The visual effects correlated with Malina's design intentions. For example, *Jazz*, the last in the short series of works Malina made using his "interrupter system," consisted of eleven different shapes. These were illuminated by eight lights that flashed on and off roughly every second and three lights with longer periods of about five seconds. Malina designed the timing of the interrupters to be deliberately imprecise but, taken together, *Jazz* could present 2,048 (i.e., 2^{11}) possible combinations in a random order. Malina found the unpredictability pleasing. As he later wrote, the flashes had a "definite rhythm," which became more noticeable to him when listening to, in keeping with the piece's title, fast-paced bebop.[38]

Malina continued to experiment, trying things like using incandescent lights whose output changed continually rather than blinking on and off. But, as 1955 was drawing to a close, Malina found that he had "more ideas and problems with the electrical parts of the pictures" than he could solve himself. He hired Jean Villmer, a young electronics engineer living in Paris, and the solution they converged on reversed Malina's initial approach.[39] Rather than varying the light's intensity that was transmitted through fixed media, they started experimenting with steady lighting that passed through both moving and static parts.

This eventually led to what Malina began calling his "lumidyne system." It was, ultimately, the technique which contributed the most to his reputation as an artist. Malina built a lumidyne in layers. At the back of a wooden box, hidden from the viewer, was an electromechanical system consisting of lights and small motors. Also included were gears and drive chains from toy Meccano sets that Malina borrowed from his children. The "rotator"—a transparent plastic disk on which Malina painted solid colors or patterns—provided a second layer. The motors turned one or more of these pieces. In front of this layer, Malina placed another piece of painted

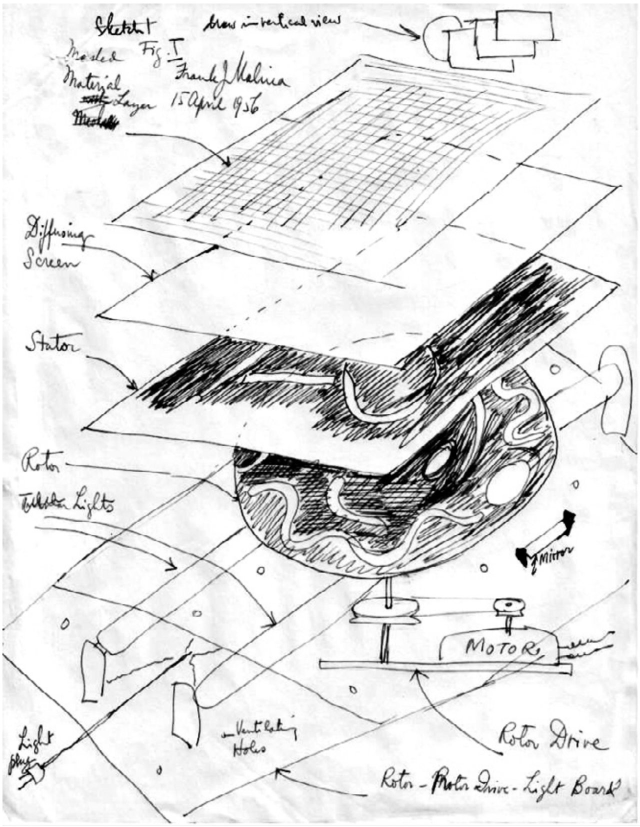

Figure 1.5 Sketch by Malina, April 1956, of his electro-kinetic lumidyne system; note the various layers, which, when combined, created the desired visual effect. Image courtesy the Malina Family Archive.

plastic called a "stator," which didn't move. Finally, at the front of the piece, Malina sometimes added an unpainted "diffusor" screen.[40]

The muted and subtle visual effect of a lumidyne is difficult to convey with words. But Malina's system produced continuous, infinitely varied, and fluid images that gently and gradually moved and shifted. Malina designed his lumidynes so their visual cycles would typically unfold over a few minutes. Lumidynes that had more than one motor could turn painted rotors at different speeds, creating more complex visual effects. If Malina wanted, he could also introduce some randomness into the composition by having a gear or chain deliberately slip every so often. In keeping with Malina's traditional, painterly background, the whole ensemble was compact enough so that his lumidynes could be hung on the wall like traditional works.[41] In a fascinating variant of independent discovery, Gyorgy Kepes (of whom we will learn more later) was experimenting at the same time with similar techniques, eventually producing a series of “kinetic light murals” for corporate patrons such as KLM and RadioShack during the early 1960s.[42]

Malina found that producing stimulating visual effects was itself rather simple. What proved more challenging was presenting a “controlled expression of the artist’s intention.” Malina approached this process empirically. He accounted for basic variables such as the distance between the rotors and the stator or the speed with which the motors moved the parts, giving each piece its own particular rhythm. At first, however, he found it hard to stop thinking about a lumidyne’s technical features—the lights, chains, motors, and so forth—and concentrate on the composition of the artwork itself. “It was as though,” he said, employing a musical analogy “a composer for the piano were excessively conscious of the mechanism which causes the strings to make the sounds.”[43] To evaluate the effect of adding a part or changing a color, the apparatus would have to be taken apart, modified, and then put back together before being plugged back in. Outside the studio, Malina (and other kinetic artists) realized that many galleries and museums were not set up to display electrical works. To help alleviate concerns of gallery owners, he might include a statement on the back of his pieces noting that, if malfunctioning, it could “be put in order by any electrician or radio repair man.”[44]

Sometimes, Malina would work in collaboration with one or more assistants. On the inside of *Cosmos*, made in 1965, one finds the signatures of six other technicians who assisted Malina in its construction. Between 1956 and 1966, Malina created more than 140 works using some variant of his lumidyne system. Although the size of the pieces varied considerably—for instance, he made a series of “Constellation” pieces that were only ten inches per side—Malina remained true to his longstanding interest in using scientific or technological themes as subject matter. In conceptualizing and designing his lumidynes, Malina began with a representation—a thing, sometimes a human figure, but more likely a scientific object or natural phenomenon—to which he applied color, light, and, most critically, actual movement. Unlike, however, the kinetic pieces by the Swiss artist Jean Tinguely, Malina eschewed satire and social commentary in pursuit of a contemplative visual experience that emphasized line, color, and composition.

Malina remained convinced that art could have utility beyond the personal response it stimulated in viewers. Malina imagined art (and, more broadly, aesthetics) could provide something familiar from his first career as an engineering researcher: predictive power. Might not it be possible, after sufficiently rigorous experimentation, to develop a theory of aesthetics "capable of predicting into the future the effect a work of art will have on people?"[45] Art, in other words, could benefit the research of perceptual psychologists and other professionals. Malina's ambivalent relationship with formal writing about aesthetics later became a leitmotif in his correspondence when he was editing *Leonardo*, the art-science journal he launched in 1968.

By the late 1950s, Malina was starting to consistently place his electro-kinetic paintings in galleries and museums throughout Europe and the United States. However, his inability to leave France—his passport was not reinstated until 1958—circumscribed the art he could see in person and limited the artists he interacted with to those passing through Paris. But, even as his repertoire of artistic techniques was expanding, something serendipitous happened that took his art career in new directions. Frank Malina discovered Thomas Wilfred.

LIGHTED, ANIMATED, AND EVER-CHANGING

Although they were born nearly a quarter-century apart and met one another on just a few occasions, Thomas Wilfred and Frank Malina had a good deal in common. Both possessed strong personal ties to Europe and became visual artists after working in other professions. Ideas and imagery from astronomy and space exploration inspired them and both men also tried to commercialize their artistic techniques. The artworks they constructed ranged in size from small pieces suitable for decorating a living room to much more ambitious works built for public display and larger audiences. Malina and Wilfred also saw their artworks as something to be viewed in a contemplative, even meditative, frame of mind. Each artist planned his compositions as works that would unfold over lengthy periods of time (in some of Wilfred's pieces, this might be on the scale of months). Wilfred sometimes worked with an assistant or two, similar to the experimental approach Malina adopted for making his artworks.

In terms of materials and underlying technologies, Malina's lumidyne system and Wilfred's *lumia* represented approximate technical means to achieving similar aesthetic ends. But the two artists differed greatly in how, outside the precise language of the patent applications they both eventually filed, they described and presented their techniques. Malina, still showing the years of training he had as a research engineer, wrote about his practices in clear, almost clinical terms while Wilfred deployed a florid, sometimes almost mystical style. This difference arose, in part, from the ambitions each had for his technique. Where Malina saw his lumidyne system as a method for making art, Wilfred envisioned *lumia* as an entirely new art form to rival music and sculpture.[46] The two also differed in terms of how they highlighted their technical skills. Whereas Malina was quite happy to be identified as an engineer-turned-artist, Wilfred consistently downplayed his experiences working as an auto mechanic before he became a visual artist.

In theory, Malina could have encountered Wilfred's work during one of the times he visited the Museum of Modern Art in his pre-UNESCO days. MoMA had received Wilfred's *Vertical Sequence II, Opus 137* from the artist in 1942 but the museum's records suggest, however, that it wasn't displayed until 1951. By this time, Malina was living in Paris.[47] And MoMA didn't acquire its second Wilfred composition (*Aspiration, Opus 145*) until 1955, by which point Malina was unable to leave France. Moreover, between the end of World War II and the mid-1960s, the art establishment paid little attention to Wilfred, lowering the chances that Malina might have read about him. Therefore, it's almost certain that Malina had never heard of Wilfred when he first started making lumidynes in 1956. More likely is that Malina learned about Wilfred in 1957 from an American collector and arts patron named Marion McCaw who was in the process of buying a lumidyne from Malina. McCaw lived in Seattle—her husband had made a sizeable fortune there in the telecommunications business—but regularly visited New York museums and communicated with curators in the Northwest.[48]

Once Malina *did* learn about Wilfred, his response was perfectly in line with his earlier career as a research engineer: that is, he filed for patent protection. "I do not wish to stop others from using the technique," he said, "but I wouldn't like someone else to stop me from using it. Let's hope the idea has not been patented."[49] Malina contacted an American lawyer and soon secured copies of Wilfred's prewar patents. He was no doubt relieved to see that his approach to combining light, color, and motion was distinct from Wilfred's method. "So far as I can make out," he wrote a friend, "he has not hit upon the simple system I am using."[50]

Additional motivation to patent his work came from another quarter. In March 1958, his piece *Changing Times* won a prize at the Salon Comparaisons in Paris. A few weeks later, Malina met with a representative from France's national electric company who had seen the winning artwork. He suggested that the engineer-artist's lumidynes could be used, as Kepes had done, to make visually arresting advertising displays. In May 1958, Malina's lawyer filed an application for a US patent titled

"Lighted, Animated, and Everchanging Picture Arrangement." French and British patent applications followed. Although discovering Wilfred's work provided Malina with incentive, he told his family that "like so many technical men, I do not enjoy the nuisance of drawing up patents. I guess it is mostly laziness."[51]

Although Malina maintained his familiar demeanor of modesty and self-deprecation, the reality was that the Soviet Union's launch of its first satellites had brought a surge of media inquiries and a steady flow of old engineering colleagues who visited him in Paris. Von Kármán, his former mentor, for instance, wanted Malina's help in starting a new professional organization to promote spaceflight. Officially formed in 1960, the International Academy of Astronautics promoted global cooperation for the peaceful exploration of space.[52] Malina's renewed involvement with rocketry, although not on the technical side, had a noticeable effect on his artistic output. In 1958 and 1959, for example, he only made seventeen lumidynes compared with fifty-three in the next two years.

However, in 1958, another issue was much more on his mind than Sputniks or future patents. All throughout the summer, Malina and Andrew Haley, a longtime friend and legal advisor, exchanged circumspect letters about the reinstatement of his American passport. Chief among Malina's concerns was the "question that we have for so long been worried about," that is, probes into his past political activities. The government's official form asked Malina his occupation. "ARTIST-PAINTER," he replied. But when it came to answering if he had ever been a member of the Communist Party (the form specifically instructed "WRITE YES OR NO") Malina penned "NOT TO MY KNOWLEDGE."[53] For whatever reason, government officials accepted this unorthodox response. So, after more than seven years, Malina had a passport and could finally leave France.

The next year, Malina and his family traveled to New York. High among his priorities was visiting MoMA where he could finally inspect Wilfred's works in person. Malina was relieved to see that Wilfred used a different sort of electromechanical system to create his luminous, colored compositions. On a subsequent trip to the United States, Malina finally met with Wilfred, now in his midseventies, at his suburban New York studio and the two of them corresponded occasionally, though quite amiably, after that. When subsequently writing about his art making, Malina always took care to give credit to Wilfred while explaining how he developed his own lumidyne system independently.

By the end of 1959, Malina had started to invest greater attention into a plan he had been considering for some time. With some sponsorship from a French banker who had a longtime interest in space exploration, Malina started a small company. Electra Lumidyne International would make electro-kinetic paintings that Malina imagined being deployed for advertising or decorative purposes. Progress with the company proceeded at a measured pace. Malina was now traveling extensively while the continued success of his Aerojet stock removed any immediate financial imperative. Occasionally, commercial opportunities materialized—Air France, for example, hired him to make a display for a window along the Champs-Élysées—but, overall, his company tended, as he phrased it, to have "lots of pregnancies, but few deliveries."[54]

Malina found a new commercial possibility toward the end of 1961. Andrew Haley brokered a connection between Malina and executives in General Electric's Radio and Television Division. GE's executives asked him to design an "audio-kinetic object" for the home market that would produce a pleasing visual display while it responded to music and other ambient sounds.[55] As public attention for his invention and art form continued to grow, Wilfred had also looked to commercialize his invention, designing, for instance, his Clavilux Juniors and other home instruments, sometimes enclosed inside fancy wood cabinets, that played compositions with preprogrammed tempos and chromatic output, which owners could modify slightly.

After studying prototypes provided by GE, Malina redesigned his basic lumidyne technique. His new "reflectodyne system" projected light from an incandescent lamp through moving color filters that was then reflected off polished metal pieces and onto a diffusing screen on the device's front. The reflecting surfaces were mounted on motor-powered "trees" that turned at varying speeds. Getting the device to respond to sound required much more complicated electronics, so he hired a Paris-based electrical engineer to help him. Perhaps eager to avoid his earlier mistake of not researching antecedents, he also commissioned literature surveys that reviewed how artists had previously experimented with light, color, sound, and motion.

Although a management change at General Electric ended the effort, Malina used what he learned to make several new artworks with the reflectodyne technique as well as some audio-kinetic (what the artist sometimes called "kusic") pieces.[56] Intrigued at first, he found spectators' response to the audio-kinetic objects unsatisfying and he eventually returned to the less complicated lumidynes. Nonetheless, his personal interest in the psychology of perception continued to grow. Malina's curiosity took him to Belgium where he visited Albert Michotte, a Belgian experimental psychologist. Malina was surprised to find a machine in Michotte's lab whose basic principles resembled a lumidyne. Michotte's simple instrument used a moving

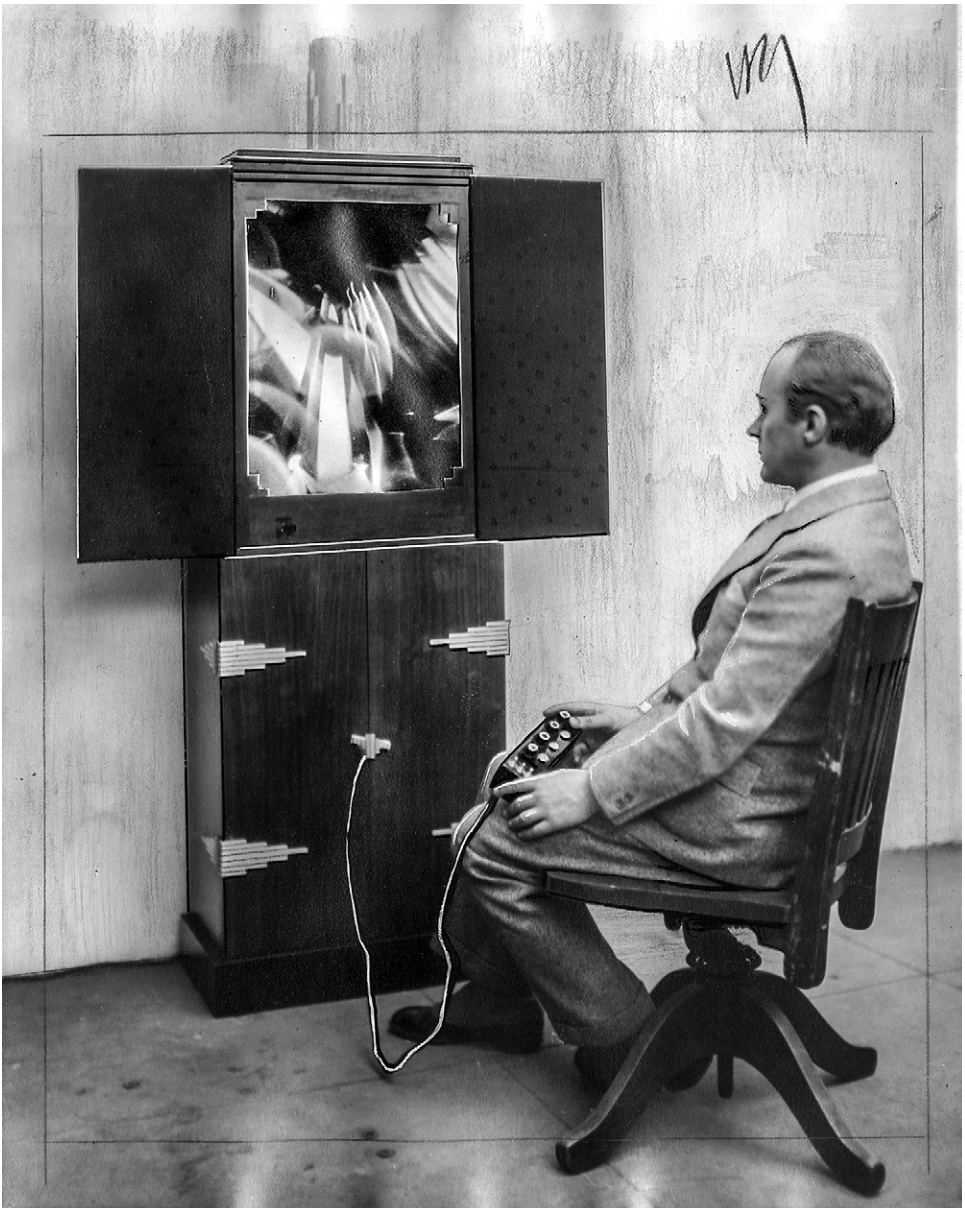

Figure 1.6 Thomas Wilfred, ca. 1930, with one his Clavilux Junior units. Image courtesy the Yale University Art Library.

Figure 1.7 Malina adding details to his 1965 lumidyne *Cosmos*. Image courtesy the Malina Family Archive.

piece of paper on which he had drawn designs. This rotated in front of a stationary piece of paper that had designs cut out of it. Michotte used it to study the perceptual reactions of patients as the two parts moved relative to one another. This and other devices Malina learned of where light, motion, color, and even sound were integrated fostered his interest in how art, aesthetics, and psychology might speak to one another.[57]

The technological advances of the Space Age, Malina claimed, challenged modern artists to "find some aesthetic significance" in them.[58] In 1965, Malina started working on a new lumidyne called *The Cosmos*. Pergamon Press, a publisher of scholarly journals, had commissioned Malina to make it as a representation of the union of the arts and sciences that would be displayed in the lobby of the company's Oxford headquarters. *The Cosmos* was massive. At approximately eight feet wide, ten feet tall, and 826 pounds, it was the largest lumidyne Malina had made. Inside its handmade wood and metal case, Malina installed 120 electric lights and twelve electric motors. These parts illuminated and moved two layers of plastic pieces that Malina painted with opaque and transparent colors. Finally, in the very front of the piece, Malina placed a large piece of translucent plastic, which softened and diffused the

Figure 1.8 Making the monumental *Cosmos*. When finished, the work was nearly ten feet tall and weighed some 826 pounds. Image courtesy the Malina Family Archive.

bright light. The effect was such that, for example, a static part painted blue and a moving one painted yellow and red yielded shifting patterns of green and purple.

Malina based his design on astronomical images and what he imagined astronauts and cosmonauts had seen when orbiting the earth. Painted circular shapes representing the planets were situated above a bottom band of color and hovered below a sun that radiated slowly changing shades of red, white, and orange. Situated between the sun and planets were three nebulae, executed as filaments of light moving back and forth. Finally, at the top, Malina placed his interpretation of star

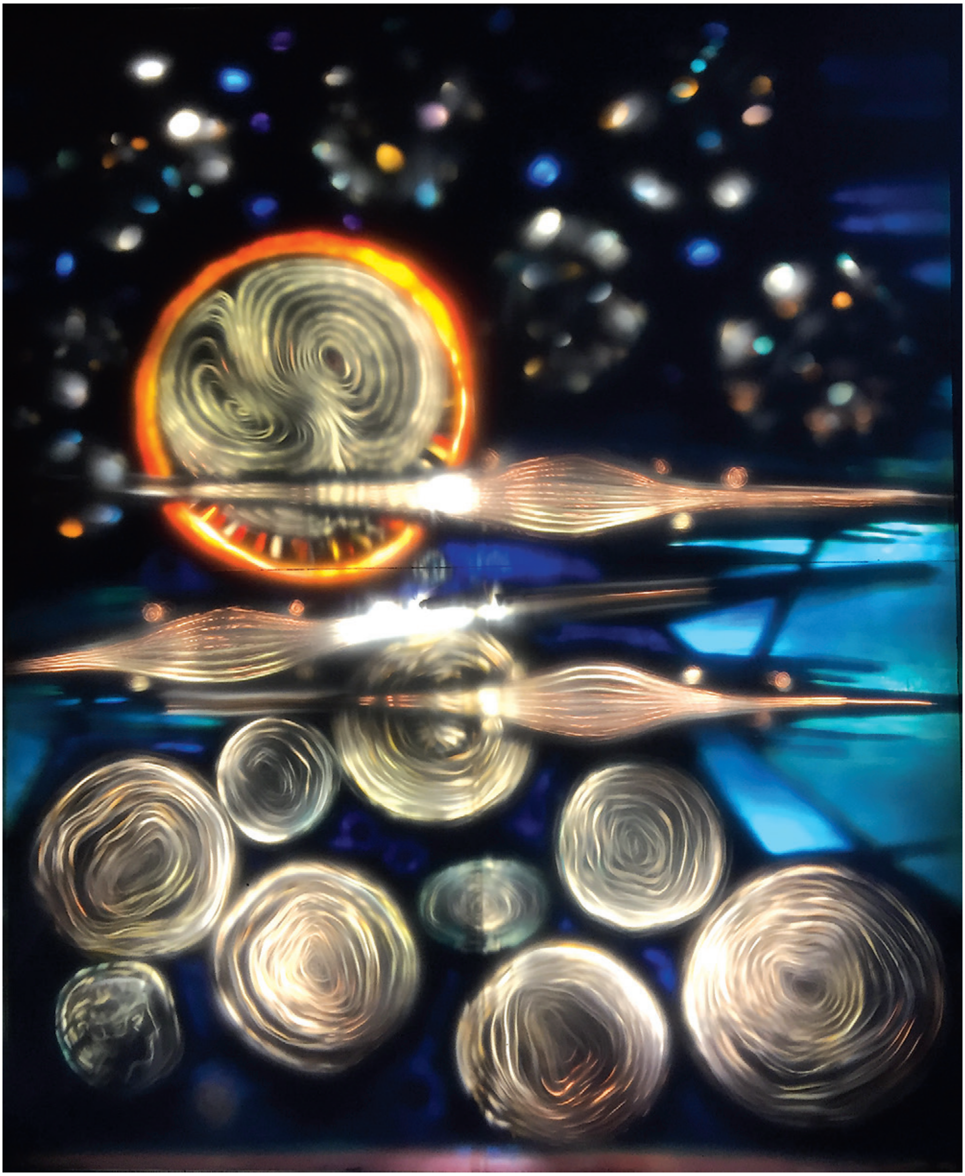

Figure 1.9 Malina's 1965 piece *Cosmos*, restored and on display at Oxford Brookes University. Image courtesy the Malina Family Archive.

clusters, colored lights that slowly oscillated and pulsed. The overall effect was an elegant, continuous yet stately display of motion and shifting color. In 1965, a British television crew filmed Malina as he made *The Cosmos*. The short film clip that survives shows him overseeing assembly of the work's various layers in Oxford with Malina adding a few last touches of paint. He then closes the massive cabinet, flips a switch, and looks on appreciatively.[59]

Malina's discovery of Thomas Wilfred's art helped him discern a distinction between the customs that scientific and engineering communities accepted as normal and those followed by artists. As Malina saw it, after a scientist or engineer did research, a "report is written for publication" that explains the work done and cites "other pertinent works."[60] In contrast to scientific research, art was "non-accumulative" in that it did not build on a prior base of published knowledge. As a result, the ethics of the artist's profession did not necessarily compel one to give proper credit to previous work. Just as troubling to Malina was his observation that, because "artists are generally mute" when it comes to describing their own work, this task instead fell to a "separate class of verbalists" to explain what the artist did and how it was accomplished.[61] This was akin to having the results of scientific experiments written by science journalists—a profession that was blossoming in the 1960s—rather than the researchers themselves.[62] These views, derived from his personal experience, influenced his vision for *Leonardo* as a forum where artists and researchers could present and properly document their ideas.

CRITIQUING THE KINETICISTS

Around the time I began writing this book, I had a conversation with a curator at a major museum about Frank Malina. It was not a familiar name to them. I explained how Malina had transitioned from a professional engineer to an artist and showed some examples of his work. In response, they asked, "Yes, but was he an *important* artist?" I later realized, after I talked with more art historians and curators, that this was a polite way of asking, "Was his work any good?" The question caught me off guard because, as a historian who studies technologies and the communities who make and use them, I wouldn't normally start by asking whether someone was a *good* engineer or scientist. I would instead begin with the premise that they *were* an engineer or scientist, full stop. And so, regardless of whether Malina was (or is) an important figure in the art historian's canon, he *was* a professional artist. He made art, he sold art, and he showed art in galleries, exhibits, and museums around the world for almost three decades. *Time* magazine even featured one of his pieces in an article on contemporary art.[63] Although I've no interest in adjudicating his status as an artist, it is entirely appropriate to consider how his works were received during the time he was most active.

As an artist, Malina was atypical. To start with, he began his career unburdened by the financial constraints many beginning artists faced. Money from his Aerojet stock enabled him to build his own studio, buy supplies, travel, take time off when he wanted, and, when complicated projects called for it, hire other artists and technical experts to help him. This independence influenced Malina's relation to the larger Paris art scene. At the same time, his passport issues seriously circumscribed his exposure to trends in the art world outside of France for several years. Finally, his artistic sensibilities were primarily shaped by conversations and personal experiences he had in the 1930s and 1940s while working on rocketry in the United States.

As he refined his lumidyne system, Malina remained uncommitted to showing his works at any one gallery. In general, he disliked Paris's gallery system, believing it encouraged owners and critics to champion a particular artist or technique independent of aesthetic value or novelty. For example, in his view, Denise René and her gallery promoted only certain kineticists, such as Victor Vasarely, Nicolas Schöffer, and Jean Tinguely. One gets a sense that Malina favored something similar to what he experienced as an engineering researcher where peer review and scientific merit, not personal connections, were more responsible for one's success (at least in principle, if not practice). Just as Malina the rocketeer refused to directly participate in the military-industrial complex after World War II, Malina the artist remained skeptical about the "gallery-museum" complex.[64]

Despite his aloofness from the Parisian gallery system, Malina maintained an exceptionally active social life. At his house on the outskirts of Paris near the Bois de Boulogne, haphazardly curated groups of guests regularly gathered for dinners, debates, and chess matches that went long into the night. Malina's carefully maintained guestbook records how writers, poets, philosophers, and other humanists routinely mingled with physicists, biologists, and rocket engineers.[65] On any evening, kinetic artist Wen-Ying Tsai, museum director Jean Cassou, or British constructivist artists Anthony Hill and Gillian Wise might cross paths with folk singer Joan Baez (her father, a physicist, had worked with Malina at UNESCO), or have a glass of wine with visiting polymaths such as Jacob Bronowski, Joseph Needham, or Buckminster Fuller. While C. P. Snow—another Malina acquaintance—lectured in public about the divide separating the "two cultures," the eclectic community gathered in

Malina's living room proved that the gap could be bridged. In both his professional work and his personal life, we can see Malina as deliberately well-rounded—"*uomo universale* . . . the Burckhardtian version of the Renaissance man"—equally adept in conversation with humanists and scientists.[66] It was no coincidence that he later adopted *Leonardo* for his journal's name.

In the late 1950s, as kinetic art grew in popularity, newspapers and art journals started to pay increasing attention to Malina's techniques and expanding oeuvre. Once Malina could travel internationally and exhibit his work more easily outside of France, the number of articles featuring his work grew considerably. The seeming incongruity of his professional background—path-breaking engineer becomes professional artist—offered an appealing narrative for many writers, especially after the space race began. In the 1960s, Frank G. Popper emerged as one of the most active and widely published writers on kinetic art. Impressed with Malina's work, Popper helped bring international attention to the former rocketeer's artistic blend of motion, electric light, and color.

Raised in Vienna where he worked briefly as a textile engineer, Popper spent World War II in England at a forestry camp for refugees from Central Europe. He arrived in Paris in 1955 with his spouse, Hella Guth, a surrealist-abstract painter. As he became acquainted with the Paris art scene, Popper met gallery owners such as Denise René as well as Malina and other artists. Soon, Popper was a regular visitor at *chez Malina* who he found "very open to all forms of artistic expression."[67] Initially intending to write a dissertation on Proust, Popper instead became caught up in the new electronics-based techniques that artists and composers were experimenting with in France and elsewhere.[68] Attracted by the new medium's "aesthetic, culturally topical, technical and spectacular qualities," Popper decided to refocus his studies on the history of movement in art. As his profile as an art critic rose, he organized several ambitious exhibits of kinetic art. Kinetic art, Popper wrote in 1964, represented a sincere "attempt to reconcile Art with Science," views which suggested the durability of C. P. Snow's ideas.[69]

Not surprisingly, when art writers like Popper were looking to establish a genealogy of light-and-motion art, they tended to begin with pioneering works made by Thomas Wilfred. Another common point of reference for Popper and other art writers was abstract cinema works made in the mid-twentieth century. For example, Popper referenced films by the Scottish-Canadian artist Norman McLaren who, for a period of time in the 1950s, worked for UNESCO. McLaren would sometimes directly draw or scratch images on film, which could then be projected and displayed. Another touchstone was the “visual music” by animators such as the German-American artist Oskar Fischinger, who contributed to works by several Hollywood studios, including the award-winning 1940 Disney film *Fantasia*.[70]

As kinetic art became increasingly popular with audiences and curators, Popper and other art writers situated Malina’s work in conjunction with other contemporary artists. Wilfred’s work, which critics were gradually rediscovering in the 1960s, was a point of reference, tying Malina to prewar light-and-motion works. Another main point of comparison was Paris-based artist, Nicolas Schöffer.[71] Given the differences between their best-known works, it was a curious juxtaposition with shared interest in movement providing the only obvious common element. Malina (and Wilfred) resolutely adhered to a painterly tradition, working largely alone or, when needed, with a small team of assistants. With a few exceptions, such as the mural-like *Cosmos*, most of Malina’s works were meant for private display and measured reflection. Moreover, Malina typically executed his art on a modest scale. Designed to be aesthetically pleasing, it differed from other prominent 1960s-era trends by not purposefully aiming to be cold, visually jarring, or disruptive, even ugly. It was art meant to encourage contemplation and relaxed appreciation.

In contrast, the Hungarian-born Schöffer gained attention in the early 1960s for proposing works conceived on an entirely different size and scale. As a result, their realization required considerable input from teams of professional engineers and technicians. In this sense, Schöffer serves as a link to later ambitious and large-scale projects undertaken by people like Billy Klüver. Schöffer’s projects, one critic said, crossed a border from “traditional art object” to a “technologically inspired visual spectacle.”[72] In many cases, Schöffer proposed making monumental art on a scale similar to what Tatlin and his fellow Russian constructivists imagined in the 1920s. Deeply influenced by cybernetics—the study of the relationships between people and machines where communication, feedback, and self-regulation were central concepts—Schöffer based his designs around what he termed “spatiodynamics.”[73] Defined in various ways by the artist, this concept related the visual appearance of kinetic sculptural works to their three-dimensional movement and timing. In his thinking, Schöffer also considered the ways in which his artworks, through their movement, appearance, and even their sound, altered the physical surroundings in which they were placed.[74]

In 1961, for example, in the Belgium city of Liège, Schöffer unveiled his *Cybernetic Tower*.[75] Standing 170 feet tall, its suite of sensors registered ambient environmental changes such as wind, temperature, and humidity. The information collected went to a computer that, in conjunction with electric motors, varied the movement of large rectilinear metal blades and vanes. Sunlight was reflected and diffused off their polished metal surfaces while, at night, beams of multicolored light were projected onto the tower.[76] Schöffer integrated his works into the local environment, using the glass windows of a nearby office building as well as the Meuse River itself as projection screens. Philips, the giant Dutch electronics company, contributed significant technical and financial support to build Schöffer's tower, as well as other cybernetic pieces he designed later.

Producing spectacles like *Cybernetic Tower*, however, put Schöffer in the role of project manager as much as artist. Engineering expertise, industrial production, and, of course, lots of complex electronics bankrolled by a major technology company were essential to make the works Schöffer became best known for. Although both Malina and Schöffer used light and movement, they did so on completely different scales. But the idea of commercializing their particular aesthetic techniques—Schöffer, like Malina, took out patents—appealed to both artists. However, the ties that Schöffer and other Paris-based kinetic artists like Jean Tinguely had to Denise René and her gallery would have raised a red flag for Malina. In any case, nothing in Malina's correspondence suggests any social familiarity with Schöffer, despite their relative proximity to one another.

Malina's artworks exploited a painterly approach combined with electromechanical systems. The result was electro-kinetic objects that were, as Popper described—using a somewhat condescending phrase that helped end their friendship—"designed on drawing-room proportions."[77] In contrast, Schöffer's glitzier, cybernetic-informed sculptures presaged the large-scale works that would later both intrigue and infuriate critics of the art-and-technology movement. Whereas Malina's pieces were meant to be seen in a gallery or displayed in one's home, thousands of people could simultaneously experience art spectacles like *Cybernetic Tower*. Kinetic art's increased accessibility and popularity encouraged some cultural arbiters to question its seriousness, especially when it was executed on the scale Schöffer aimed for.[78] The fact that Schöffer helped decorate Voom Voom, a posh nightclub in Saint-Tropez, probably didn't help matters.

Malina established few connections to some of the new collectives devoted to making and theorizing kinetic art in the 1960s. For example, in 1960, a small group of Paris-based artists coalesced as the Groupe de Recherche d'Art Visuel. Better known as GRAV, its members sought to integrate industrial materials and ideas borrowed from science and engineering into their artwork. As the group's name suggests, research was a central tenet. A statement released by GRAV in April 1962, for instance, claimed their approach to making art reflected the "method and technique of the scientist."[79] Meanwhile, at roughly the same time in Milan, a cohort of artists formed Gruppo T and made artworks with industrial resources such as strobe lights, plastic, and small electric motors. In 1962, with support from the typewriter and computer company Olivetti, Gruppo T showed their work throughout northern Italy. Umberto Eco's text for the catalog described their works as both "kinetic" and a "singular dialectic between chance and program" but in a way that "does not negate spontaneity." Two years later, the "Arte programmata" show traveled to London and the United States, accompanied by a translation of Eco's catalog.[80]

Malina, who had actually worked for years as a research engineer and managed teams of workers and technicians, expressed skepticism toward the large-scale efforts that, for many critics, defined the first wave of art and technology. While he saw some justification for a collective approach, such groups needed a clear leader with an initial artistic vision that others worked with. Although he didn't specifically call out groups like GRAV, Gruppo T, or ZERO (a West German collective that emerged in Düsseldorf in 1957), he judged the trend of artists "blindly imitating the modes of work in science" to be of dubious value. In both scientific research and art making, Malina concluded, a team-based approach was "basically uncongenial" to creative people who possessed "original, adventurous, and nonconformist minds."[81] Malina's views indirectly reflected concerns being voiced by scientists at the time about the place of the individual researcher amid the ever-larger teams of Big Science. They also set him at odds with efforts by groups such as Experiments in Art and Technology, where collaboration and teamwork were not just encouraged but provided the goal.

One contemporary art trend that Malina *did* have an interest in was concrete poetry, a kind of experimental writing developed in the 1950s. Concrete poetry exploited a poem's visual features—the arrangement of words on the page, its typeface, and graphics—to help convey meaning. Malina often discussed concrete poetry and kinetic art with Reginald "Reg" Gadney, a young family friend who occasionally helped Malina in his studio. Soon after Gadney began university work at Cambridge, he and some friends founded a student group that promoted new art forms through exhibitions and articles in small-circulation magazines. They were especially struck by the "close connection" they saw between concrete poetry and kinetic art. Both deployed "optical designs that conveyed visual movement."[82] Besides helping organize an exhibition that included one of Malina's lumidynes, Gadney showed

Malina's art to Syd Barrett, then an arts student in Cambridge, who would later become the singer for the psychedelic rock band Pink Floyd.

By the mid-1960s, Malina had exhibited his art in more than forty different museum and gallery shows throughout Europe. Curators routinely included lumidyne pieces in major shows, including the mammoth "Kunst-Licht-Kunst" (Art-light-art) show that Frank Popper organized with support from the Philips company. But it wasn't until 1965 that Malina showed his work in a major American venue. (Before his death in 1981, he participated in more than twenty group or solo exhibitions in the United States.) John Canaday, an art critic for the *New York Times* complained that the Whitney Museum's "Annual Exhibition of Contemporary American Painting" was a "rather jumbled affair." But he praised Malina's *Away from the Earth*, a large and radiant lumidyne inspired by spacecraft trajectories, as the "stylistic conclusion" to 1965.[83] With shows such as these, Malina had reached a goal he had set for himself more than a decade earlier and found success in what he still occasionally derided as the "art game."

Canaday was right about the timing. That same year, Denise René organized another large and ambitious show of kinetic art in Paris. Meanwhile, in February 1965, thousands of visitors began flocking into MoMA's galleries for a blockbuster display of op art called "The Responsive Eye." Perhaps not surprisingly, after the quintessential middlebrow magazine *Time* profiled what German artist Hans Richter had dubbed "The Movement Movement," art critics predicted kinetic art's imminent demise.[84] As Malina continued to sell lumidynes to collectors and friends—prices ran as high as several thousand dollars in today's currency—he was already building the foundation for another career change. Soon he would begin publishing a journal to bridge art, science, and technology and encourage artists to communicate in ways familiar to scientific researchers. Malina embarked on his new venture at a point when the worlds of both professional engineers and artists—their sensibilities, their patrons, and their relations with one another and society at large—were in the midst of profound flux. To understand how the first major wave of art and technology transformed from a set of small-scale, personal experiments to an organized and well-funded undertaking, we need to explore the divides, both real and imagined, that existed between engineers and artists in the long 1960s.

2

FLUXES

> A creative engineer is an inventor, a species of artist. He's no organization man. . . . Impose conformity on him and he must cease to be creative.[1]
>
> J. H. McPherson, 1965

The trenches had been dug decades earlier. But never before had such colorful and caustic volleys been exchanged.

Sitting on one side of the battle line was a "rough, uncouth fellow wearing boots and an open flannel shirt"—the Engineer. Having no manners nor wanting any, his fleeting familiarity with the arts and literature was "limited to cheap movies" and "comic books." Defiantly "crass, materialistic, insensitive," the only intellectual tools he allegedly needed were "a transit and a slide rule." Career victories usually happened when he "pushes jobs through by beating up his men with his bare fists."

Staring at him from across the divide was the Artist. A "pale, ascetic dreamer," the "arts man" was devoted to modern art, music, and literature, talking "incomprehensibly about all three" while nursing a crippling addiction to books. Possessing "pinkish" politics and "forever in need of a haircut," neither practical skills nor scientific knowledge were a burden to bear. What professional accolades he received came primarily via his considerable "gift of gab."[2]

These caricatures appeared courtesy of a study conducted in the mid-1950s by the American Society for Engineering Education. It was one in a steady succession of reports produced after World War II by professional societies and universities about what knowledge and skills novice as well as experienced engineers needed to possess. These concerns grew in urgency as technology became one of the key arenas for fighting the Cold War. Engineering and business leaders worked to redesign university curricula, adding classes and programs that would reflect the new technological needs of the national security state as well as a rapidly changing industrial landscape. Engineering schools gradually replaced traditional, often hands-on training with increasingly abstract "engineering science" courses that made students learn more basic physics, chemistry, and math instead of professional skills. By 1965, a student's roster of classes would have looked dramatically different from what Frank Malina and other engineers-in-training had learned just a few decades earlier.[3] Associated with this was engineers' ongoing preoccupation with their professional status. Engineers continued their struggle to be accepted as the professional equal of scientists instead of rough-hewn louts who acquired their expertise on a gritty job site and not in some clean and tidy lab.

Economics and demographics helped drive engineers' pursuit of reinvigorated educational goals. New industries such as aerospace and microelectronics stimulated a near-desperate need for engineers' talents and helped catalyze their community's growth. The majority of these technical experts worked for a handful of America's biggest corporations: Ford, General Electric, and AT&T.[4] Over time, young engineers often graduated from building and maintaining large technological systems to managing them, moving from the shop floor to corporate offices.

With more and more young engineers being trained in narrower and more specialized topics, engineering leaders and educators asked how they could best construct a sufficiently well-rounded education. An increasingly rigorous engineering curriculum left little room for electives, so plans for integrating the arts and humanities presented a persistent challenge. And yet the hope was that the arts and humanities could provide more than just a "cultural veneer" and actually serve a utilitarian purpose by enhancing engineers' creativity.[5] But what exactly was a "creative engineer"?[6]

As they earnestly wrote reports addressing these questions, engineering educators came into close quarters with a debate that, in a somewhat different guise, was already roiling outward from the lecture halls of Cambridge and Oxford to the pages of highbrow literary journals. In October 1956, the British scientist-turned-novelist C. P. Snow publicly voiced his concerns about the widening gap between humanists and scientists, noting that they shared "little but different kinds of incomprehension and dislike."[7] Less than three years later, Snow took the stage at the Senate House in

Cambridge to give the annual Rede Lecture. His talk, titled "The Two Cultures and the Scientific Revolution," offered a broader diagnosis of the problem. The inability of literary scholars and scientists to understand and communicate with one another was not just an intellectual loss, Snow claimed, but something that threatened the ability of modern states to address the world's problems.[8]

Throughout the 1960s, "the two cultures" existed as both a phrase and a commonly understood set of ideas. It provided a reliable reference point for artists, art writers, and engineers to justify art-and-technology collaborations and situate them in a larger framework. And, as we'll see, it proved so remarkably durable that traces of Snow still appear in twenty-first-century reports and articles about the nexus of art, technology, and science.

Snow's diagnosis, derivative from the outset but possessing great persuasive power, appealed to engineers and scientists who sought to redesign their approaches to educating tomorrow's technologists. Even as it ripened into a bland phrase of the sort commonly found in commencement speeches—its vagueness was a strength—the idea of two incommensurate intellectual cultures suggested a need for introspection and improvement. When Snow's argument migrated to the United States, it lost its original British baggage and assumed a more simplified form. In the process, it became a shorthand term for something both more anodyne and yet also reflecting some uniquely American concerns. Snow's argument, if not his exact phrasing, was routinely adopted by engineering educators, especially as they reimagined what an engineer should ideally know and do. Coupled to this were assumptions about the working world of engineers employed in industries made prosperous by the Cold War.

SNOW'S STORM

Despite considerable differences in physical appearance—jokesters wisecracked that Snow's "well-rounded" nature wasn't limited to his intellect—Frank Malina and C. P. Snow shared some biographical features. Both grew up in lower-middle-class families and attended second-tier schools (University College, Leicester for Snow and Texas A&M for Malina) before moving on to elite institutions for graduate training (Cambridge and Caltech, respectively). Both men had their views toward science and the humanities shaped by their experiences in the 1930s. Like Julian Huxley, Snow and Malina considered science and engineering as hopeful endeavors with the power to address social inequities and economic mismanagement. Likewise, in the 1930s, both men made significant contributions to research (although Snow's forced retraction of his claim to have artificially synthesized vitamin A left lasting professional and emotional damage). Just as Malina decided to become a professional artist, in the 1930s, Snow turned his energies toward a career as a novelist.

After World War II ended, Snow continued writing fiction but also began a new career as a well-placed civil servant, shuttling between bureaucratic appointments in Whitehall and British industry. In the 1950s, Snow's "Strangers and Brothers" series received widespread attention from critics, winning awards and becoming book-of-the-month-club selections. Its eleven installments followed the life of Lewis Eliot—Snow based the character on himself—as he climbed from provincial beginnings to a law career before becoming a Cambridge don and influential senior adviser. With books like *The New Men*, which appeared in 1954, Snow used fiction as a vehicle to describe the industrial world of the Atomic Age and the role of liberal technocrats in managing it.

When C. P. Snow—soon Sir Charles and, later, Lord Snow—started speaking about the divides he perceived between the two cultures, he joined a dialogue that had been under way in his country for some time. In the nineteenth century, for example, biologist Thomas H. Huxley and poet Matthew Arnold debated the merits of a scientific versus literary education, discussions which were as much about British social and institutional conceits as intellectual values.[9] Given his multiple careers ("By training I was a scientist: by vocation I was a writer"), Snow believed this was a conversation—albeit not necessarily an original one—to which he was uniquely suited to contribute.

Although his 1959 Rede Lecture bestowed international recognition on Snow, he already had been presenting his ideas on the two cultures for several years. Earlier articles in the *New Statesman*, the *Atlantic Monthly*, and *Nature* gave Snow the opportunity to practice his argument's basic premise. In his lecture, his diagnosis sharpened as he derided literary intellectuals as an insular community of pessimistic Luddites responsible for Great Britain's national decline. In contrast, it was scientists—Snow famously cast them as optimists with the "future in their bones"—who could spread progress and prosperity at home and abroad. Snow claimed that the gulf between the scientific and literary cultures did not just deprive the two communities of intellectual enlightenment. As more nations sought independence and decolonization, political leaders would need technical and scientific experts to guide and assist them. But with the British civil service dominated by those with a backward-looking literary orientation, Snow claimed the Soviet Union, where scientists and engineers were more influential, won an advantage.

Figure 2.1 Charles Percy Snow, as depicted in a 1962 sketch by Polish-born British expressionist Feliks Topolski from his *Chronicle No. Ten*. Photo by Feliks Topolski/Hulton Archive/Getty Images.

Part of the power of Snow's phrase lay in its binary nature—the image of *two* cultures was easily grasped—and this aspect remains what is most widely referenced today. But regardless of how scientists and literary intellectuals were separated from one another by a "gulf of mutual incomprehension," *both* communities, Snow noted, shared an antipathy for engineers and their knowledge about the "industrial society of electronics, atomic energy, [and] automation."[10] Despite their neglected status, Snow, whose grandfather had been an engineer, argued that technologists had made Britain's rise to world dominance possible. Still, Snow said, scientists and humanists alike remained "dim-witted about engineers and applied science," failing to see the challenges engineers tackled as "intellectually exacting" problems with their own "satisfying and beautiful" solutions. The result was a "snobbism" that relegated engineers to "second-rate minds." Throughout the first wave of art-and-technology activity, art critics and journalists likewise often expressed similar surprise that engineers possessed any special knowledge and skills which demanded its own form of creativity.

Snow's diagnosis sparked a storm of heated objections, ad hominem attacks, and retaliatory articles, the most spectacular of which came from literary critic Frank Raymond Leavis.[11] His essay's subtitle ("The Significance of C. P. Snow") suggests the level of personal antagonism the debate rose (or fell) to. In order to discredit Snow's claim that he understood *both* cultures, Leavis dismissed Snow's accomplishments as a novelist. Like the chasm between the two cultures itself, the Snow-Leavis volleys drew deeply on long-standing divides in British society when it came to class, education, and authority.

Seen another, equally nationalistic way, the fight was also about the role of scientific and technological expertise in postwar Britain with Snow largely cheering for the technocrats.[12] Besides transforming Snow into a well-known public intellectual, his lecture (and the rancorous debate it provoked) turned "two cultures" into a metonym. The phrase offered an abbreviated and efficient, if not always precise, way to signal a more complex set of concerns while acquiring an "occult force," one writer noted, "comparable to that of 'Strength Through Joy' or 'The Great Society.'"[13] As a result, throughout the 1960s, Snow's phrase acquired considerable interpretative flexibility, making it a universal solvent into which all sorts of concerns, anxieties, and remedies could be mixed.

Although Snow's lecture provoked an immediate sensation in Great Britain, initial reactions in the United States were more muted. It received no notice, for example, in the *New York Times* until a lengthy review of Snow's ideas, now converted into a modest-size book, appeared in January 1960. J. Tuzo Wilson, a Canadian geophysicist, gently rebutted some of Snow's claims while demonstrating, *pace* Snow, his own familiarity with contemporary literary culture. Just as there were some scientists whose contributions were uninspired and second rate, were there not also some humanists "alive to the terrifying speed of change" that modern science and technology caused?[14] Nonetheless, Wilson concluded that "no one has yet refuted" Snow's basic argument.

In the months that followed, Snow's diagnosis, now transplanted to the United States, generated an avalanche of discussion. Columbia University made the book required reading for all freshmen while then-senator John F. Kennedy praised Snow for his insights on a pressing "intellectual dilemma." American book clubs began to offer *The Two Cultures* to their members.[15] As a result of this exposure, what was originally formulated to diagnose to specific British conditions started to diffuse into American public discourse. Speaking of the two cultures at an American engineering conference, however, became something quite different than debating in the pages of high-brow British magazines.

The different significance Snow's phrase acquired in the United States can be traced, in part, to renewed attention, bordering on obsession, that policy makers, industry leaders, and researchers gave to science and technology circa 1960. A prime catalyst for this was the Soviet Union's launch of the first artificial satellite in 1957 and the accompanying anxiety that the United States trailed its Communist challenger in technological prowess. Sputnik galvanized American efforts to reform engineering and science education as Congress passed the National Defense Education Act. This massive infusion of funds, coupled with the needs of the space race and the arms race, dramatically increased the number of young people entering fields like physics and engineering.[16] Consequently, discussions of the two cultures that engineers and scientists had in the early 1960s are best imagined with an insistent Sputnik-generated "beep-beep-beep" chirping in the background.

In the years following Snow's original lecture, articles and letters agreeing with, referencing, or rebutting his claims appeared in American science and engineering journals. *Scientific American*, for example, ran a lengthy piece by historian Asa Briggs who expressed some agreement with Snow's general argument while challenging Snow's binary reductionism.[17] Reviews found in *Physics Today*, *Nature*, and the *Bulletin of the Atomic Scientists* struck similar notes.

Engineers may have felt the thrust and parry of the debate even more acutely than their scientist colleagues. The distinction in public discourse between engineers and scientists remained elusive and indistinct. And, although Snow had clearly praised the importance of engineers (his "applied scientists"), when the two cultures discussion migrated to the United States, this point was frequently lost in the flurry of articles Snow's talk precipitated. It's not hard to imagine many engineers believing they were not much welcome in *either* culture or that, in the stereotypical view held by some people, they didn't *have* a professional culture. Ironically, Snow himself perpetuated the image of the uncultured engineer reluctant to challenge the social order. His 1954 novel *The New Men* juxtaposed liberal-minded physicists with the "people who made the hardware," judging the latter as those most likely to be "conservative in politics, acceptant of any regime in which they found themselves, interested in making their machine work, indifferent to the long-term social guesses." The engineers, Snow broadly claimed, "buckled to their jobs and gave no trouble" while it was the scientists who were the "heretics, forerunners, martyrs, traitors."[18]

Despite university classes that increasingly focused on teaching complex scientific principles—solid-state physics, quantum mechanics, aerodynamics, and theories of jet propulsion all became part of the Cold War engineer's curriculum—the standard bearers for science in the 1960s remained physicists. Consequently, one can sympathize with engineers who may have wanted to join the two cultures debate, as they faced two challenges. One was reminding people that they too were a part of Snow's broader "scientific" culture. This was relatively easy compared to the second task: demonstrating that they also were creative, liberally educated professionals. "Humanizing the engineer" eventually emerged as a potentially valuable outcome, which might happen when engineers collaborated with artists.

Of course, one rebuttal to Snow's sweeping claims was that neither scientists nor humanists were a monolithic group. The same, of course, can be said for engineers. Let's consider a single yet especially significant segment of their community. By the mid-1960s, almost 20 percent of America's engineering community worked primarily on electronics of some sort (up from about 10 percent just fifteen years earlier) as Cold War military needs and the growth of computer and microelectronics industries drove market demand for their skills.[19] The translation of new laboratory breakthroughs, such as the transistor and the integrated circuit, into an array of commercial products spurred the need for even more electrical engineers. Enjoying considerable job security, electrical engineers displayed the most enthusiasm and interest when it came to joining art-and-technology collaborations in the 1960s. Likewise, the technologies that artists wanted most to experiment with—such as lasers, computers, complex lighting and sound systems, and holography—were exactly the topics in which electrical engineers had expertise. So how these technologists anticipated and reacted to the general diagnosis of a "two cultures divide" assumes a central importance.

In February 1962, an editorial in the leading journal for electrical engineers noted that "we . . . are finding ourselves drawn, with increasing frequency, into discussions of the interrelationships of science and the humanities."[20] Whether such a gap actually existed—and whether it was the responsibility of engineers to "humanize" themselves or, instead, for humanists to learn more about technology and science—were topics engineers rightly had to debate. Nonetheless, the essay—which cited C. P. Snow, Aldous Huxley, and playwright William Saroyan—concluded that, as responsible professionals, electrical engineers were obliged to recognize "value judgments" and "social responsibility" as they carried out their work.

The letters engineers wrote in response likewise drew on literature, philosophy, and classics so as to challenge conventional stereotypes of their profession. Opinions on Snow's diagnosis varied widely. The "body scientific," one person noted, bore the responsibility for "closing the gap between human cultures" in part because of the new dangers it had unleashed on the world. Another respondent, bringing the question down to less apocalyptic terms, argued that the public first needed to see that "scientists and engineers are people too." As such, some are "well-informed on politics, art, literature . . . some are dull, some are clever, some are shrewd, some naïve." But where scientists were freer to speak publicly, engineers, who more often than not were employed by companies, "were expected to remain silent" on issues that might affect their employers. Other readers resorted to engineering analogies, claiming that humanist-scientist comparisons created a "whole darn system [going] into wild oscillations" that could only be fixed by "inserting a corrective feedback circuit." Opinions aside, all of the letters agreed that *some* problem existed which needed attention. "Does anyone, really, seriously, think that we can do without a dialogue between the scientists and the humanists?," one reader asked. While thoughts about the two cultures sometimes soared to planes of abstraction, engineers, electrical or otherwise, saw the education of future engineers as one of the best places to build bridges between cultures and create more "humanized engineers."[21] Indeed, as electrical engineer James Lufkin argued, while citing both former Harvard president (and professional chemist) James Conant and poet Mark Van Doren, "liberally educated engineers" were the community best suited to communicate with both scientists and the educated public.[22] But the question remained of how exactly a new community of well-rounded technology experts should be built.

HUMANIZING ENGINEERS

The dialogues that engineers were having with one another and with experts from other disciplines were part of a much more expansive conversation about American education in the postwar period. In 1943, James Conant, for example, commissioned a prominent study, published two years later as *General Education in a Free Society*, which proposed that all students receive a holistic liberal education that would foster creativity and more flexible, open minds.[23] The Harvard report—a published version sold over 40,000 copies—emphasized a need to balance coursework in the humanities and sciences so as to avoid the sort of noncommunication and specialization later seen as pervasive in Snow's two cultures. The search for an ideal mix of classes took on especial significance at schools such as MIT, which after World War II, transformed itself from a polytechnical school oriented more to the needs of industry into a modern research-based university that, as one MIT president phrased it, was "polarized around science, engineering, and the arts."[24]

The end of World War II marked a major shift toward the emphasis on "engineering science" in university education as complex mathematics and scientific theory were stressed. This contrasted sharply with the prewar situation when students would learn skills like drafting and take courses in design. As a result, prewar engineering students were quite possibly *more* attuned to the skills of visual artists than their postwar colleagues. After 1945, the change in curricular focus toward abstract scientific theory proved especially true for electrical engineers. Frederick Terman, an electrical engineer who, as a dean and then provost at Stanford, led the school's rise to national prominence, described how the training of future electrical engineers would increasingly emphasize basic science "at the expense of traditional engineering subjects." A cartoon that accompanied his article shows a young engineer with a slide rule exclaiming "I can calculate the deflection of a beam!" His engineering professor responds, "Who cares?"[25] In Terman's (influential) view, this new generation of highly trained electrical engineers would occupy a position somewhere between "pure science" and "traditional engineering" and, once in the workforce, they should expect to work in collaborative, interdisciplinary environments.

Even as engineering courses were being redesigned to include more cutting-edge science, engineering educators were wrestling with how to also best insert more liberal arts education into an already crowded curriculum. Although C. P. Snow's claim of a culture gap helped provide some rhetorical justification for these efforts, proposals to give the humanities greater prominence in engineers' university training emerged years before his ideas became prominent. One of the more notable efforts, based on extensive site visits and interviews, was carried out in the mid-1950s by the American Society for Engineering Education. It emphasized that producing young engineers who appreciated the liberal arts meant discarding stereotypes while also encouraging engineers to see the arts and humanities as valuable in their own right. Hoping to do more than just make engineers "acceptable in polite society," the humanities could enhance engineers' understanding that "every professional act has human and social consequences."[26] Statements such as these acquired greater urgency toward the end of the 1960s, when student activists, opponents of the Vietnam War, and critics of large, impersonal, and destructive technological systems increasingly labeled engineers as amoral technocrats beholden to the corporations they served. Such charges insinuated themselves into the art-and-technology movement, as we'll see later.

Education experts who wanted to see engineering students enrolled in more economics, management, or sociology courses—subjects which claimed, at least, some patina of quantitative rigor—faced an easier task than those encouraging studies in literature and the visual arts. But, traditionally, engineering was a highly visual activity with design standing as a central component of what a practicing engineer actually did. Moreover, talents in drafting and drawing, as well as the ability to envision and represent objects in space, had long been part of engineers' critical skill set. So, how did humanities and engineering faculty at a prominent research university like MIT imagine the visual arts could be further woven into the education of future technologists?

Like Harvard, MIT embarked on a major study to help chart a new course in the Cold War era. Ironically, the committee, chaired by chemical engineer Warren K. Lewis, excluded humanists even though one of the study's recommendations was closer integration of the humanities into the undergraduate curricula.[27] But the visual arts were given short shrift, an omission that precipitated, in the best tradition of academic institutions, more follow-up studies. MIT's administration created the Committee for the Study of the Visual Arts, which was led by leading art history professors and directors of major East Coast museums. Consultants included Rudolf Arnheim, an art critic and perceptual psychologist, and Josef Albers, a former Bauhaus painter. Joining them was Hungarian-born Gyorgy Kepes, another artist with a Bauhaus connection. Throughout his career, first at the Institute of Design in Chicago and then as a professor of the visual arts at MIT, Kepes sought to reconcile art and science by creating forums for discussion and practice. His efforts culminated, as we'll see later, with the establishment of a new center at MIT where established artists could collaborate with engineers and scientists.

John E. Burchard, dean of MIT's humanities and social sciences school, released the result of the committee's efforts in 1957. Beginning with a quote from British philosopher and critic G. K. Chesterton—"art consists of drawing a line somewhere"—Burchard stated MIT's first major task was deciding where that line should be drawn with respect to the education of future engineers and scientists. The report observed that too many people who graduated with university degrees were "visually illiterate."[28] Addressing this shortcoming certainly resonated with Kepes who had long promoted art as a means to "train the eye."[29] As Kepes wrote in his 1956 book *The New Landscape in Art and Science* (a work to which Burchard contributed a foreword) "vision is itself a mode of thinking." It was this characteristic that MIT sought to instill in its students. While research in engineering or science "makes sense by an appeal to reason," art "grows from a reaction to something seen or felt." Fostering a robust visual arts program, the report claimed, would coordinate "eye and hand to qualify the theoretical by the empirical."[30] (MIT's motto, after all is *Mens et manus*, i.e., "mind and hand.") In other words, the arts might serve as an effective bridge across disciplinary divides.

MIT's School of Architecture—Kepes's institutional home—had already expressed interest in developing some sort of "experimental arts program." Starting in 1957, for example, MIT students could take courses in art history as well as try their hand at art making. To lead MIT's studio arts program, Kepes recruited painter Robert Preusser. Initially, the school's students, for whom "Picasso is more an enigma than Einstein," presented him with a challenge.[31] Rather than trying to teach students basic skills like sketching or pastel work, Preusser decided to play to their inherent strengths by drawing on their existing fields of study. Electrical engineering students, for example, took tiny circuit boards and figured out how to print photographs on them while those studying metallurgy could experiment with metal casting.

Even in this one, rather brief, report, it's possible to sense the tensions inherent in efforts to promote the visual arts at a research-oriented institution in the midst of massive expansion fueled by Cold War-derived defense grants and contracts.[32] Were these courses to be an entertaining diversion for already overworked students? Or did they carry their own intrinsic value, pragmatic or otherwise? Advocates for the visual arts often (and understandably) resisted the idea that their expertise existed *only* to humanize engineers or, worse, provide them with a patina of cultural sophistication. As Preusser later noted, he and his colleagues had to learn how to engage the minds of budding technologists “without diluting the essence of the art experience or encouraging a superficial dabbling.” The goal was not to convert engineering students into artists but rather to showcase how technology, science, and art *all* relied on “imaginative thinking and inventive procedures.”[33] Later, when advocates for the art-and-technology movement focused their attention likewise on practicing engineers, similar beliefs and goals undergirded their rhetoric and rationales.

These tensions between instrumentalism, pragmatism, and idealism appear in other lengthy reports that piled up like so many bricks on the desks of education reformers throughout the 1960s. Although these might not reference the “two cultures problem” explicitly, they didn’t necessarily need to. Building rapport between engineering, science, and the humanities had already been absorbed by educators and many practicing engineers as a goal worthy of pursuit (if indeed not easily attainable). For instance, Julius Stratton, an electrical engineer who also served as MIT’s president in the early 1960s, sprinkled references to the unhealthy bifurcation of the modern university into his speeches.[34]

The seemingly esoteric question of what university students should be taught also found its way into more widely read discussions about American society. In the fall of 1956, Simon and Schuster published the now-classic book *The Organization Man*. Authored by William H. Whyte, a writer for *Fortune* magazine, the book advanced the idea that the needs of large corporations had systematically stamped out individuality and creativity in favor of conformity. Whyte’s book stayed on the *New York Times*’ bestseller list for much of 1957, becoming an influential midcentury work of popular sociology.[35]

Whyte devoted a whole chapter, titled “The Practical Curriculum,” to the question of proper balance in university education. As he saw it, humanists and scientists alike were becoming marginalized by all the young people “studying to be technicians.” And when it came to educating these future engineers, Whyte stressed that, for many, the idea of having engineers learn more arts and humanities remained a controversial, even unwanted, goal. As evidence, he cited an article in *Technology Review* (a magazine, ironically, that MIT published) whose author argued for *less*, not more, liberal arts education. In light of Cold War threats from the Soviet Union, it claimed that “no silly humanities” should unduly burden engineering curricula.[36] Whyte’s counterpoint was that denying engineers and scientists exposure to the liberal arts contributed to conformist thinking and, ultimately, led to Soviet-style collectivism. As Whyte painted it, the liberal education of technologists was both practical as well as patriotic.

By the mid-1960s, the national conversation regarding the "two cultures" had shifted from a phrase that conveyed a sense of crisis to something of a cliché. Much of the fury, if not the sound, emanating from two cultures debaters had dissipated. In its familiarity, something—maybe not contempt, but a certain whiff of condescension—emerged instead. Samuel Florman, a civil engineer who authored an impassioned critique of 1960s-era antitechnology sentiments, wrote, "All of us today are in favor of liberal education for engineers, just as we are in favor of motherhood and the American flag—instinctively, almost mindlessly."[37] However, even as intellectuals picked apart the stereotypes and simplicities of Snow's original formulation, the goal of bridging cultural gaps and expanding educational vistas had become part of the landscape of engineering in the 1960s. Regardless of how flawed the two cultures as analysis might be, as a concept it offered art-and-technology advocates a useful touchstone. It also gave a rationale for those engineers who bravely decided to cross the cultural no-man's-land and shake hands with artists. However—as we'll see—once the first art-and-technology wave started gaining prominence, funding, and supporters, people from both sides of the two cultures stood up and challenged this rapprochement.

THE ENGINEERS' SENSIBILITY

In 1963, Time-Life Books launched a new book series called the Life Science Library. With C. P. Snow serving as a consulting editor, it explained modern science and technology to the general public and offered colorful illustrations of the people—almost always white men—who worked in these worlds. When it came to showcasing the work of physicists or molecular biologists, the series' editors had a relatively straightforward task. There were many prominent discoveries and equally famous scientists to draw on for the slickly produced volumes. But when it came to describing the engineers' profession, the editors found themselves facing a challenge. Who, exactly, was an engineer? There were no Albert Einsteins, Marie Curies, or Edwin Hubbles to serve as well-known reference points that would resonate for the average reader.

Time-Life's volume *The Engineer* instead suggested technologists in the 1960s composed a vibrant community permeated by both confidence and a sense of crisis. Despite their essential role in (literally) building the modern world, the engineer remained an anonymous "blurred figure, his exact role imperfectly understood." Delineating *what* engineers did was also perplexing. It was "difficult to determine where the scientist's work ends and the engineer's begins" as both "look alike, talk alike, worry over similar mathematical equations." Even with their extensive training—described as "education without end"—many people still imagined the engineer as some "solitary boot-shod adventurer," whose professional work consisted of "damming rivers and driving roads through the wilderness." This stereotype endured despite the fact that most engineers worked "behind desks or in laboratories . . . with slide rules, computers, and microscopes." Fitting no single mold, the engineer was "part scientist, part inventor, part technician, part cost accountant," yet almost always a trained specialist in some narrow field.[38]

From popular books like this, which attempted to describe (and sometimes critique) the technologists' working world, as well as their own writings and recollections, we can sketch a rough picture of the engineers' *sensibility*. By this, I mean how engineers approached, engaged with, and experienced—in terms of concerns, pleasures, anxieties—their profession. The concept of a sensibility, usually reserved for discussing art and aesthetics, speaks to collective modes of viewing the world.[39] What emerges is a consistent but sometimes internally contradictory ensemble of opinions that many engineers shared about themselves and their place in 1960s society. Appreciating the sensibility of engineers helps us better understand that more than a few of them were willing to step across cultural divides and collaborate with artists.

A variety of evidence, ranging from mass-marketed books like *The Engineer* to publications from engineers' professional societies and the recollections and opinions of individuals, helps us recover a glimpse of this sensibility. While the specific concerns expressed over thousands of pages of articles and advertisements in venues such as *Mechanical Engineer*, *Chemical Engineering Progress*, and *IEEE Spectrum* are field specific, there is enough commonality that a representative picture emerges. Data from sociological studies, such as surveys funded by the National Science Foundation in the mid-1960s, helps fill in this picture.[40]

A critical component of the engineers' world in the mid-1960s was confidence. Engineers displayed an overall sense of self-assurance, derived from prosperity and seemingly endless possibility, which contributed to their willingness to collaborate with artists. Engineers had solidly established themselves as upwardly mobile members of the middle class. There were almost one million engineers of all kinds working in the United States by the mid-1960s. Engineers represented the second largest segment of American professionals—only school teachers composed a larger community—and it was the most common occupation pursued by white-collar men. The Cold War's technological needs coupled with the affluence of the 1960s gave engineers increased visibility, a sense of responsibility, and job security.

Those engaged with electrical systems and electronics engineering saw some of the largest gains in job growth and career opportunities. In 1950, manufacturers of electrical products and equipment employed something like 44,000 people, almost all of them white, middle-class men. This professional community grew about 8 percent per year such that, by 1966, some 160,000 electrical engineers practiced their profession in the United States.[41] At the same time, the unemployment rate for electrical engineers was a miniscule 0.4 percent, about a tenth of the national average. The scores of advertisements for well-paying positions that appeared in professional magazines every month reflected this swell of confidence, as did student enrollments. In 1965, nearly half of MIT's class of engineering graduates specialized in electrical engineering.[42] In short, to be an electrical engineer in the 1960s was to join a booming professional community where economic opportunity and job prospects were plentiful.

A distinguishing feature of engineers' college education and subsequent professional life was an increased emphasis on cutting-edge technical knowledge grounded in basic science. The basic curriculum in fields like electrical engineering was steadily infused with courses in circuit design and solid-state physics, while new electronic devices such as computers and lasers became subjects practicing engineers needed to know about. Stanford's Frederick Terman predicted that electrical engineers would, reflecting their expanding intellectual world, eventually be called "electronics scientists."[43] Relative to counterparts in other fields, electrical engineers were among the best educated, being the most likely to have earned a bachelor's degree and also most likely to pursue advanced degrees.

However, a corollary to engineers' engagement with new electronic technologies, products, and applications was a perceived need in the community for continuing education and training. As *IEEE Spectrum*, the flagship journal of the Institute of Electrical and Electronics Engineers, phrased it for its 150,000 readers, "Always a student!"[44] There was, however, a darker side to this cheery-seeming pronouncement. As engineering became more science-based and infused with computers and methods of systems management, engineers worried that their technical knowledge might soon become obsolete. Ernst Weber, the Institute for Electrical and Electronics Engineers' (IEEE) first president, claimed that the time in which an engineer's knowledge lost about half its value had, by 1960, shrunk to less than ten years.[45] There was considerable irony in this as engineers themselves were often blamed for a culture of planned obsolescence that marked Cold War America.

Continuing education, of course, was the “antidote for obsolescence” as were advanced degrees and attending conferences. Engineers were encouraged to keep up with the technical literature, a task that grew ever more challenging. In 1946, American organizations for electrical engineering published about 3,000 pages of material across three journals. Two decades later, the page count had shot up to 30,000 pages spread over forty-two increasingly specialized publications.[46] To assuage engineers' anxieties, corporate advertisements promised recruits the opportunity to learn new skills through continued education. “We won't let an engineer become obsolete,” claimed Hewlett-Packard.[47] Another firm likened engineers at competing companies to hamsters spinning on their wheels while their own employees were continually challenged by “one-of-a-kind problems.”[48] Eager for variety and new experiences, a small cohort of engineers sought intellectual revitalization through means other than taking more night classes. Collaborating with artists gave them a chance to apply their skills in a new setting.

The surge of membership in the electrical engineering community was boosted by an influx of people from other fields, especially physics. This contributed to the ever-blurry distinction between science and engineering when it came to professional identity. But, with a few exceptions, it was a man's world. Page after page of engineering magazines were illustrated with images of white men wearing white dress shirts and nondescript ties. The cultural processes through which engineering and technology became male-dominated domains had begun decades earlier. But, by the 1960s, the effects were systemic and some engineers found the results stifling. One survey of ten American engineering programs in 1964 showed that out of the nearly 20,000 students, only 175 were women. And, across the entire country, fewer than 2,000 women were enrolled in engineering departments and, statistically at the time, women had a relatively high dropout rate. Put another way—in 1960, the entire community of future women engineers could be comfortably seated in a large university lecture hall.[49]

This masculine world was reflected not just in statistics but in fiction. When Dell published Joseph Whitehill's 1959 novel *The Way Up*, the paperback's cover described the main character, Paul Mockley, as “the engineer in the grey flannel suit . . . capable of handling everything—but women.”[50] Central to its plot was an anomaly, a female coworker—a “woman in a man's shoes”—whose presence at the electronics factory where they worked together challenged Mockley until romantic currents flowed. Based on images of the engineers' workplace as depicted in professional magazines and advertisements, it's quite possible that collaborating with a woman artist might have been the first time that many male engineers had the opportunity to actually work with someone of the opposite sex. Seen more broadly, collaborating with artists offered engineers a chance to encounter greater diversity than they typically found at the office or factory.

If engineering in the 1960s was largely a white man's world, it was also a militarized one. Engineering journals were replete with articles and advertisements featuring military systems that companies like Motorola and Hughes Aircraft contributed parts and expertise to. Ads from General Dynamics, for instance, boasted about the sophisticated electronics that the F-111, its newest fighter-bomber, carried. Poignantly, even as engineers encountered these advertisements, artist James Rosenquist finished another interpretation with a mural he titled *F-111*. The eighty-six-foot-long painting, finished in 1965, fused a sleek image of a menacing looking aircraft with scenes of American consumer goods and a rising mushroom cloud. Just as the F-111 interposed itself in Rosenquist's painting, images of submarines, satellites, radar dishes, and missiles appeared with an almost relentless frequency in the magazines engineers read in the mid-1960s.

In keeping with engineers' longstanding concerns about their professional status, in December 1964, the establishment of a National Academy of Engineering was announced. Based in Washington and operating in parallel with the century-old National Academy of Sciences, the new organization was seen both as a honorific group and a delivery system for policy advice to the government. The founding of the National Academy of Engineering signaled that engineers were professional partners, with knowledge and skills that overlapped with their scientist colleagues, in serving the country's economic and security needs. After decades of laboring in the shadow of scientists, the community of engineers had arrived.

Or had it? To read engineers' professional journals is to enter a mildly schizophrenic world. On one hand, the community's fortunes were positively booming as jobs were plentiful and the economy was robust. Prominent efforts like the space program touted the importance of engineers' labors to the public. But, relative to scientists, engineers still felt marginalized and anonymized.[51] When the press lauded progress made in launching rockets, developing nuclear power, or desalinating water, engineers often complained that it was *scientists* who received the credit.[52] After watching television coverage of the Gemini 10 flight in 1966, a scathing letter went to CBS anchorman Walter Cronkite protesting how scientists' work was praised "without mentioning the contribution of engineers." CBS staff resorted to etymology and pulled from the "twelve-volume Oxford" to justify their word choice, claiming scientists and engineers were both "knowledge producers." This response failed to satisfy the executive director of the American Institute of Industrial Engineers who noted that such a fine distinction was likely lost on the "millions of 'little guys' who watch TV" but didn't read the Oxford English Dictionary.[53] To add insult to injury, university-trained engineers—some holding advanced degrees—were still regularly conflated with less educated *technicians* who carried out routinized tasks and maintenance.[54]

Industry employed about 70 percent of all American scientists and engineers, a fact that made university-based researchers an anomaly, not the average. Nonetheless, on those infrequent occasions when engineers and scientists working in industry *were* considered, the normative baseline was still provided by their university-employed counterparts. The view from the ivory tower of engineers, and industrial research in general, was both patronizing as well as misinformed.[55] This picture was further distorted by the preference journalists and writers gave to university-based researchers, a trend exacerbated by the relative reticence (perhaps prompted by concerns about security or corporate secrecy) of engineers and industrial researchers to describe their working worlds. As a result, academics and the general public alike based whatever vague images they had of engineers on unreliable information. Similar issues and tensions later arose in the art-and-technology movement as art writers were often at a loss to understand what they did or to recognize technologists as artists' creative partners.

One element engineers correctly understood as an obstacle in their quest for enhanced status and distinction as a profession stemmed from the relationship they had with their employers. It was assumed that their place in private industry restricted their intellectual freedom as their managers sought conformity, not creativity. This, at least, was the view suggested by William Whyte, who devoted a full three chapters of *The Organization Man* to capturing the stunted life of the "organization scientist." Whyte described, for instance, how "The Organization"—corporations, federal laboratories, and even university departments—were trying to "mold the scientist to its own image." Gone were the days in which research was done by "the lone man engaged in fundamental inquiry." Instead, Whyte argued, industrial managers and other administrators wanted to "rationalize curiosity" and marginalize individual expression.[56] An example of how teamwork, not individual genius, was desired is seen in a documentary film made by Monsanto Chemical Company. As it showed young men in a lab, "No geniuses here," the voice-over said, "just a bunch of average Americans working together." As Whyte depicted it, the Organization Man was a team player who managers steered toward collaborative projects with specific goals. The push for conformity was, Whyte implied, a broader drift toward Soviet-style organization, a stark warning from a book published at the peak of the McCarthy era.

Scientists and engineers presumably encountered this pressure to conform years before they joined the ranks of industrial researchers and system tenders. The boom after World War II and then, again, after Sputnik, affected the ways in which core courses like physics were taught to young scientists and engineers as class sizes soared at American universities. Teaching efficient and repeatable methods of calculation in an assembly line manner became a dominant pedagogical style.[57] A sense of these Fordist-inflected teaching techniques can be also be seen in Time-Life's *The Engineer*. In a section profiling students' experience at MIT, a large photo captioned "A New Crop of Engineers" shows hundreds of largely identical students crammed into a gymnasium for an exam. With latecomers overflowing into the bleachers, it could be read as a gloomy image of nascent Organization Men about to enter a world of project-driven, team-based corporate research where their individual creativity would be quashed.

There is, however, another interpretation. Some engineers liked, even wanted, to be part of collaborations. Throughout the 1960s, company advertisements in engineering journals depicted teamwork not as a disturbing and distorting trend, as Whyte saw it, but as something potential employees would view as desirable. Obviously, such images can't be read as a direct statement of engineers' sensibility. But, given as they were designed to recruit new talent, such advertisements indicated what companies and advertising firms imagined engineers wanted from their professional environment. And this message differed markedly from the anti-Organization Man jeremiads people like Whyte presented.

These advertisements depicted teams and group-based activity not as something to be avoided but an environment that engineers would find comfortable. For example, a 1968 advertisement from General Dynamics showed three men in dress shirts standing around a chalkboard. Titled "The day the Avionics boys ate lunch at 4PM," it presented team-based problem solving as something so exciting that it caused the engineers to delay a meal.[58] Similar ads showed engineering as a cooperative activity, highlighting how even newly hired engineers will "experience the sheer excitement of working on a team" as they solved technical problems together.[59] A similar message from 1967 featured an engineer exclaiming that, at his company, "I'm not just a ‘part’ of a project. I *am* the project.”[60] Team-based work didn’t automatically have to mean loss of individual freedom. Based on these advertisements and dozens more like them, engineers *wanted* to work collaboratively with people, including those from other fields and disciplines, on discrete goal-oriented projects. So, for engineers who joined formal groups like Experiments in Art and Technology, project-focused and team-based efforts were already familiar territory.

And what of claims that teamwork destroyed individuals’ initiative? Again, evidence from engineering magazines suggests a different reading. Recognizing that anxiety about being branded a conformist was part of many engineers’ sensibility, industry advertisements highlighted phrases like “original thinker” and “creativity.” A 1964 advertisement featured a cartoon school of identical fish, save one creature happily swimming the other direction, and exclaiming “Welcome to left field.”[61] Xerox urged engineers to “be yourself” when sending their résumés so the company could spot “the creative, responsible, non-conformist.”[62] Breaking stereotypes of conformity extended to one’s personal appearance. “Your beard won’t bug us,” claimed Friden, a company that made electronic calculators, “We’re looking for talent, not a smooth chin.”[63] A significant fraction of the ads published in the mid-1960s implied (or stated directly) that future hires wouldn’t be company drones overseeing the routine production of devices, parts, and systems. Instead, newly hired engineers could expect to engage in novel research, some of it of their own design. For instance, General Telephone and Electronics asked electrical engineers, “Did da Vinci do the same old thing, day in, day out? Why should you?”[64] Read against the grain of the Organization Man stereotype, some engineers received a different message—they could be part of a team and yet not become some conformist trapped on the corporate hamster wheel of routine projects.

Likewise, companies eager to recruit new engineers boasted of how their workplaces offered a “favorable environment” that “enhances creativity.”[65] Electronics firm Motorola, for example, claimed its facilities were places where the engineer is “noted, not for his ability to conform—but to create.”[66] In advertisements like these, imagination and creativity were depicted not simply as attractive features of a high-tech workplace but as an essential part of what it meant to be an engineer. One might even imagine corporate managers encouragement of creativity and collaboration as an instantiation of enthusiasm for Abraham Maslow’s psychological theories. His “hierarchy of human needs” acquired tremendous popular appeal in the 1960s and suggested that the workplace could become a place for individual self-fulfillment.[67] Of course, it’s difficult to tell, given the nature of the historical record,

How can we spot the creative, responsible, non-conformist at this stage of the game?

Send us a creative, responsible, non-conformist resume.

A lot of people have heard of Xerox... in financial and business publications, on television, in general magazines and newspapers. Engineers and scientists have seen and used our equipment in their offices and laboratories.

One result of all this is that we get a lot of mail. Including resumes. More than 10,000 last year.

We read them avidly because we need many more of the kinds of people whose technical contributions have made the growth of Xerox possible. But it isn't easy. Especially when we're expanding the professional staff in many directions at once.

The thing to remember is that precious little of our technical work is *routine*. Neither can we survive and continue to prosper if we add routine people to our technical staffs. So please, if we're going to be expected to spot you at the resume stage of the game, *be yourself*. If you're a bug on detail, tell us about it. If you can gather in all the elements of a development project and see it responsibly through to fruition, relate how you handled your last assignment. If you're committed to pursuing a very special research subject and you doubt that Xerox would be interested, don't hide it. You may be pleasantly surprised.

Never forget that creative, responsible, non-conformists are very important to Xerox. We don't try to hide it. Why should you?

XEROX

An Equal Opportunity Employer

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IEEE spectrum MARCH 1965

Figure 2.2 Engineering advertisement from the March 1965 issue of *IEEE Spectrum*.

whether engineers *actually* got to be creative, but the ideals of creativity and imagination were certainly presented to them as desirable. It correspondingly formed part of their larger sensibility.

The promotion of engineering as a creative act (and its practitioners as imaginative problem solvers) emerged out of broader discussions that psychologists, sociologists, and other academics started having a decade earlier. In reaction to fears of Soviet-style conformity, creativity became identified as a positive personality trait, like autonomy and tolerance, that could be both scientifically studied and promoted to help advance American values.[68] Given the importance of science and technology in waging the Cold War, fostering more creativity—as opposed to *genius*, a trait often associated with antisocial tendencies, if not mental illness (think Vincent van Gogh)—was interpreted as an especially critical task. We might think of creativity as something to be produced and stockpiled, like ammunition, in the event of outright war.

By the time Sputnik was sweeping over the United States, academic studies of creativity were growing at a rapid rate.[69] For example, the University of Utah sponsored a series of national conferences aimed at "The Identification of Creative Scientific Talent," which the National Science Foundation funded.[70] Among its wide-ranging topics were discussions about how to measure creativity, personality studies of scientists and engineers, and how researchers responded to working in industrial laboratories. The attendees were equally diverse, including a research manager for the Defense Department, several psychologists, and a young physicist turned historian named Thomas Kuhn (soon to become famous for his now-classic book *The Structure of Scientific Revolutions*).

Not all observers were persuaded of the merits of such studies. An article by journalist Daniel Greenberg lampooned the pretensions of such conferences. Set up as a conversation between two scientists, one of them invites the other to a meeting, promising that it will be "not only interdisciplinary and multi-disciplinary, it's cross-interdisciplinary. . . . Two Cultures and all that stuff."[71] And, of course, not *all* engineers wanted to be creative nonconformists. But there were enough notable exceptions—what one recurring advertisement lauded as being "more than 'just an engineer'"—to prevailing stereotypes of the uncultured boor or gray-suited Organization Man to create a sufficiently deep pool of experts willing to collaborate with artists.

In 1965, in an essay published in the unlikely venue of *Mademoiselle*, Susan Sontag dismissed Snow's diagnosis that there were two separate creative cultures. Sontag castigated it as a "crude and philistine statement of the problem" that had gotten nearly everything wrong.[72] Chief among Snow's failings, she wrote, was his preoccupation with the differences that set literary and scientific cultures apart. In his determination to depict a binary, Sontag charged that Snow had failed to perceive a new and "potentially unitary" perspective—what she called a "new sensibility"—that a growing number of artists, engineers, and scientists all shared.

As Sontag saw it, this new attitude sprang from a "sense of 'research' and 'problems'" that was "closer to the spirit of science" than "old-fashioned art." A person's ability to appreciate the artworks of Mark Rothko and Frank Stella, a jazz piece by Thelonious Monk, or a dance performance by Merce Cunningham was, she claimed, "comparable to the difficulties of mastering physics or engineering." Nonconformist in spirit and restlessly creative, this "new establishment" was already coalescing around polymaths comfortable with blurring the lines between art and technology. Just as engineers had become familiar with teamwork, Sontag saw the "role of the individual artist" who was "in the business of making unique objects" as increasingly anachronistic.

Sontag's essay was steeped in technological imagery. She referred to art as "an instrument for modifying consciousness," where the "analysis and extension of the senses" was paramount. She called the works that resulted from such processes "an experiment" that provided viewers with "new sensory mixes." This newly emerging creative community was collectively embracing different ways of making art via methods which relied "profusely, naturally, and without embarrassment, upon science and technology." By freely exploiting new materials, media, and devices not found in the artist's traditional tool box ("industrial technology . . . commercial processes and imagery"), old boundaries that separated art from technology were being crossed and erased. What Sontag branded as the "one culture" possessed exceptional diversity. It included not only painters, sculptors, dancers, filmmakers, and musicians but also "neurologists, TV technicians [and] electronics engineers." One of these new professional hybrids, someone Sontag was certainly aware of, was engineer Billy Klüver.

3

HETERODYNE

I believed in the art world as the only serious world that existed.[1]

Billy Klüver, 1996

The evening started to unfold in Manhattan like any other. Office workers descended from their skyscraper perches and started jamming subways and trains for their commute home. At about a quarter past five, a full moon began to rise over the city in what witnesses later described as an autumn night of cold crystalline beauty. In apartments throughout the five boroughs and the suburbs that sprawled beyond, people flicked on their lights, radios, electric stoves, and television sets.

As customers' demand surged, technicians at Consolidated Edison's control center watched as gauges showing the balance of electric power throughout the region twitched, fluttered, and then veered wildly.[2] A protective relay near Niagara Falls failed, sending waves of electricity surging through wrist-thick transmission lines running to the east and south. In response to the overload, other power stations shut down, creating a cascading series of failures. Despite technicians' frantic efforts to reverse the damage, within twelve minutes, almost all of New York City had gone dark. By the time night fell on November 9, 1965, thirty million people spread over some eighty thousand square miles had no electric power. Thus began the Great Northeast Blackout.

When electricity was restored the following morning, politicians, police officers, and journalists started assessing the incident. Most striking to them was what *didn't* occur. Looting and vandalism were rare and overall the crime rate that evening actually dropped. As the *New Yorker* described it, "The Machine had broken down but nobody had gone berserk with terror."[3] Civic duty and courtesy were the norm as ordinary citizens directed traffic and helped strangers navigate dark, vertiginous stairwells in office buildings. The blackness gave residents an opportunity to see their city anew. Collectively, they "stared out at the impossible, unimaginable loveliness" of skyscraper windows dimly illuminated by flickers from candles and cigarette lighters. Stars could be seen overhead. Residents recalled a pleasing silence "as if darkness had smudged away" the usual din of traffic. The whole experience seemed less like a calamity and more like an impromptu citywide party as people made the best of the situation.

As an electrical engineer, Billy Klüver understood what caused the power failure. And, as a home owner in the north New Jersey suburbs, just a short drive from his office at Bell Telephone Laboratories in Murray Hill, the power outage affected him along with his many colleagues who lived in the city. One of these friends was artist Allan Kaprow. Kaprow had achieved recognition in the art world by organizing "Happenings"—semiorganized situations where artists in constructed environments used improvised actions and random events to break down barriers between performer and spectator. Kaprow had recently invited Klüver to join a panel at the annual meeting of the College Art Association, the major American professional society for artists and art historians. So, in late January 1966, Klüver—a slender man in his late thirties with thinning blonde hair and a personality described as "keen-witted, probably brilliant . . . but quite modest"—accompanied Kaprow to talk about traditions and contemporary art.[4]

In a presentation titled "The Great Northeastern Power Failure," Klüver compared the massive power outage to a work of art. The power grid's breakdown had encouraged people to not just be more courteous to each other but to cultivate a greater awareness of the world around them, including its technological complexity. "The whole thing could have been an artist's idea," he said, "to make us aware of something." Appreciating technology required perspectives from artists as well as engineers and scientists. "Technology," said Klüver, "needs to be revealed and looked at." To help unveil technology's presence in modern life, Klüver proposed creating a "new interface" between art and technology. It would rely on modern artists making "active use of the inventiveness and skills of an engineer" in new collaborations, something Klüver described as "not only unavoidable but necessary." These creative interventions would be unpredictable, he said, and "may or may not yield

Figure 3.1 Billy Klüver, ca. 1966, shown with the neon "R" he added for Jasper Johns's *Field Painting* (1963–1964). The image originally appeared in the April 1966 issue of Bell Labs' *Reporter*. Image courtesy the Klüver/Martin Archives.

meaningful results." But alliances between artists and engineers would "stimulate new ways of looking at technology and of dealing with life in the future."[5] This alone, he believed, was an outcome worth investing in.

To make his point, Klüver recounted his own partnerships with different avant-garde artists in New York. From an engineer's perspective, he noted, his contributions were ridiculous. Why would anyone, in the case of an artwork he and Robert Rauschenberg made together, spend considerable money and time "to control five AM radios simultaneously in one room?" Nonetheless, to get the results they wanted, artists needed engineers like Klüver. "I hereby declare myself to be a work of art—or rather an integral part of the works of art," he stated, "I am an engineer and as such, only raw material for the artist."

Klüver was being unduly modest. For more than five years, he had collaborated with well-known artists like Jasper Johns, Andy Warhol, and Rauschenberg. If anyone wanted to counter the stereotype of boorish, uncultured engineers, they needed to look no further than Klüver and a cohort of like-minded colleagues at Bell Labs. Klüver had already earned national recognition as the "Edison-Tesla-Steinmetz-Marconi-Leonardo da Vinci of the American avant-garde."[6] An exaggeration to be sure, it suggested some of the hubris and hype accompanying Klüver and the collaborations he brokered via Experiments in Art and Technology (E.A.T.), an organization he cofounded in 1966.

In the late 1960s, E.A.T. grew into the largest and most visible group in the art-and-technology movement. To the journalists and art critics who wrote scores of articles about it, Klüver appeared as a relative newcomer on the contemporary art scene. But Klüver's leadership of E.A.T. was actually a continuation, perhaps even a culmination, of personal interest in all forms of modern art stretching back two decades. It also reflected years of consideration and writing he had done about the relationships between the individual and modern technology. Drawing on an analogy from electrical engineering, we might call Klüver a heterodyne. Like the device, he took signals from two distinct sources—in this case, engineering and art—and combined them into something both different and more powerful.

Between his working hours at Bell Labs and regular forays into the Manhattan art scene, Klüver staked out territory on both sides of the two cultures divide. As a researcher at a premiere industrial lab, Klüver understood the sensibilities of his fellow engineers. Meanwhile, his personal connections to avant-garde artists afforded Klüver insights into their working world. As a result he could empathize with the concerns, successes, and anxieties of both professions. Although the two communities might have appeared distant and disengaged from one another, there were actually several topics—the desire to be seen as "scientific," anxieties about professional status, persistent uncertainties about funding and patrons, and the question of how to remain creative in working environments where accomplishments were anonymized and commercialized—which the two groups had in common.

AN ENGINEER AS WORK OF ART

Billy Klüver's parents met one another in 1927 while traveling in Spain's Basque region. His mother, Greta Lundborg, came from a wealthy Swedish family—her father owned a local railroad—while his father, Johan Wilhelm Klüver, had some vague plans to raise chickens in Spain. Despite the incongruous match, they trekked throughout Europe until November 13, 1927 when Greta gave birth in Monaco to her only son. Although christened with his father's names, they were quickly shortened to Billy.

When his parents divorced years later, Billy Klüver, now thirteen, moved from Sälen, a small village near Sweden's border with Norway, to Stockholm to live with his mother and sister. Klüver soon became a devotee of film, especially experimental cinema. He had the run of Stockholm's many theaters, from the Bauhaus-influenced Rigoletto, which could hold 1,200 filmgoers to smaller venues scattered around the city. Just as Frank Malina kept a record of what he read, Klüver diligently maintained a film notebook. Although Sweden had a strict censorship code, the teen still managed to see banned foreign films via screenings that embassies in the city hosted.[7] Klüver's fascination with film coincided with a renaissance in Swedish cinema in the late 1940s and 1950s. A "new wave" of innovative Swedish filmmaking took form as directors such as Ingmar Bergman became internationally famous and Swedish productions like *Kon-Tiki* (1950) and *Miss Julie* (1951) won major awards. At the same time, a new generation wanted to see more sophisticated and intellectually challenging films.[8]

In 1946, Klüver started university studies in electrical engineering at the Royal Institute of Technology, Sweden's most prestigious technical school. Klüver also continued attending screenings and meetings organized by the Stockholm University Film Society (Stockholms Studentfilmstudio). Later, he recalled being the only person from his technical school willing to trek across town to Stockholm University, an institution more closely identified with the humanities, where the club met. During Klüver's five year term on the group's governing board, the society's membership grew from about fifty people to over 700. The group became more active politically as it challenged Sweden's censorship rules and encouraged discussions about social and moral issues presented in films.[9]

Through the Film Society, Klüver became friends with Swedish artists and art critics who later became valuable collaborators. Besides the painter and performance artist Öyvind Fahlström, there was his long friendship with Pontus Hultén who was studying art history at Stockholm University. Hultén later directed the Moderna Museet, a dynamic new art museum in central Stockholm. Throughout the 1960s, Hultén championed the contemporary artists who worked with Klüver on different art-and-technology projects and the two Swedes organized several exhibitions together.

Klüver also developed a close professional relationship with Hannes Alfvén, one of his physics professors. Alfvén's specialty was the study of plasma physics and, from the 1930s onward, he studied the aurora borealis as a case study in how electrons moved in the presence of electrical and magnetic fields. This research helped Alfvén win a share of the 1970 Nobel Prize in Physics. Alfvén also wrote science fiction and composed music while remaining politically engaged in protesting the arms race. "I admired him tremendously," Klüver recalled, "as a physicist but also because he showed that a physicist did not have to be limited in his interests or pursuits."[10] Convinced that film could be an effective teaching tool, Klüver produced a short animated movie to help students visualize Alfvén's laboratory research. Years later, when he came to the United States, Klüver brought a copy of *The Motion of Electrons in Electric and Magnetic Fields* in the hope that a publishing company would use it as a teaching tool.

After graduating in 1951, Klüver took an entry-level engineering position at a Paris-based electrical manufacturing company. But he also attended lectures at the Sorbonne given by luminaries such as Maurice Merleau-Ponty on existential philosophy and the psychology of perception. As Klüver later explained it, he was increasingly curious about what happened when people left the comfort of their own disciplines and interacted with one another.[11] Pontus Hultén joined him in Paris and, through him, Klüver met Jean Tinguely, a Swiss-born kinetic artist. Hultén, meanwhile, joined the Parisian modern art scene and contributed to the 1955 "Le Mouvement" show at Denise René's gallery that helped inspire Frank Malina's move into kinetic art. There's no indication that Malina and Klüver met one another in the early 1950s but the possibility they might have attended the same art shows is pleasing to imagine.

Klüver's Paris employer had signed a contract with the explorer Jacques Cousteau to build an underwater television camera. With his interest in film, Klüver joined the project. The summer of 1953 found him in the south of France where he finessed his way aboard the *Calypso* as it sat anchored in Marseille and introduced himself to Cousteau. In *Le Monde du Silence*, the award-winning 1956 film that Cousteau codirected with Louis Malle, Klüver appears briefly at the *Calypso*'s bow as the ship moves through heavy seas. Once anchored above the underwater resting spot of an ancient Greek merchant ship, Cousteau's divers used the new camera system to locate and recover several clay jars. (The explorer offered one to Klüver but he declined the briny gift.)

The next year, Klüver left Europe for the United States to begin graduate work in electrical engineering at Berkeley. For his dissertation topic, Klüver pursued an interest in a new generation of solid-state devices that produced powerful microwave radiation. With funding from the air force—Klüver's topic had applications for radar jamming systems—and guidance from John R. Whinnery, a young Berkeley professor who directed the school's Electronics Research Laboratory, he completed his doctoral degree in three years, just shy of his thirtieth birthday.[12]

As he had in Stockholm and Paris, Klüver cultivated a network of friends distinct from his scholastic life. Even before he arrived in California, Klüver knew about the influential "Art in Cinema" series that experimental filmmaker Frank Stauffacher and his colleague Richard Foster operated with support from the San Francisco Museum of Art.[13] Klüver became good friends with Foster who, after graduating from Berkeley, took a position at the Stanford Research Institute, a Cold War think tank. Through Foster, Klüver met writers like Henry Miller and Anaïs Nin. This socializing, Klüver recalled, helped alleviate the "boredom" of Berkeley's electrical engineering program.[14] Foster's research specialty was the strategic forecasting of economic and military trends and, like Klüver, he was also interested in modern philosophy. Stimulated by conversations and road trips with his friends, Klüver began to think more seriously about the relations between people and the technological systems that influenced their lives.

In the late 1950s, few of these systems were as hotly debated as those associated with nuclear war. Around the time he finished his degree in 1957, Klüver drafted an essay exploring people's connection to nuclear technologies. It anticipated ideas that later became central tenets for scholars studying the social implications of technology. For instance, Klüver alluded to the momentum that large technological systems acquire despite the intentions of their creators (an idea fully developed later by historians such as Thomas P. Hughes). An overreliance on “logic, mathematics, science [and] observable facts” afforded the builders of these systems only a partial view of reality. But factors that could not be expressed in equations or computer code were just as important. At the same time, individual citizens also needed to bear some responsibility for the development of such systems and should therefore not display such fear and ignorance toward technology. The challenge, as Klüver saw it, was closing the gap between engineers and ordinary people. Artists, whose worldview and creative sense differed from engineers, could help change people’s understanding of technology.

Klüver later explained that the “seeds for Experiments in Art and Technology”—in particular, the idea that engineers and artists could and should take joint responsibility for changing “the system”—can be found in this modest-size composition. He eventually published it in *The Hasty Papers*, an unruly “one-shot review” that Alfred Leslie, a New York artist and filmmaker, put together in 1960.[15] Klüver’s essay appeared alongside contributions from J. Robert Oppenheimer, William Carlos Williams, and Jean Paul Sartre. Good company, to be sure, and as the 1960s formally began, Klüver started looking for ways to put his opinions into practice.

A COLORFUL PALETTE

Like many young electrical engineers, especially those with advanced training from elite schools, Klüver had a wealth of opportunities available to him when he completed his degree. Raytheon, RCA, and the Stanford Research Institute all offered him high-paying jobs, but he decided to accept a position in the Communications Research Department at Bell Labs’ facility in Murray Hill, New Jersey.[16] One factor in his decision was the opportunity to work with more senior researchers who shared his research interests. The fact that Bell Labs was arguably the best industrial research lab in the world didn’t hurt.

Long before Klüver arrived at Bells Labs, the organization had become a fount of technological innovation. Of the some 14,000 people it employed, only about 5 percent were formally engaged in basic research—most of the lab’s activities were directed toward the incremental improvement of existing products and systems—but these were some of the most talented researchers in the country.[17] The hierarchy among the technicians, engineers, and scientists placed employees with PhDs (typically designated as Members of the Technical Staff) at the top. One electrical engineer who worked at Bell Labs in the 1960s recalled that the Murray Hill facility presented an enticing “palette of sounds, smells, and experiences.” Conversations spilled over to hallways and cafeteria tables while labs emitted odors of soldered circuits and the greenish glows from oscilloscopes lit up darkened spaces. “Everyone,” he recalled, “seemed in a hurry on their way to a new discovery.”[18]

When Klüver started his new position in 1958, his supervisor was John R. Pierce, who was already legendary as an engineer and research manager. During World War II, Pierce had lobbied his company to adopt a device called a “traveling wave tube.” It enabled, with little distortion, the powerful amplification of microwave signals. Pierce’s dazzling research and effective lobbying helped convince American Telephone and Telegraph, Bell Labs’ parent company, to invest in a new, continent-spanning communication system. During the 1950s, AT&T dotted the landscape with microwave relay towers and Pierce, very much the visionary, wrote speculative pieces about future “orbital earth relays” that would further facilitate global communication. Pierce’s advocacy culminated with the launch of several communications satellites and he supervised engineers at Bell Labs who helped build and operate them.[19]

Like Malina and Klüver, Pierce’s interests extended far beyond engineering. This included writing science fiction under the pseudonym J. J. Coupling and composing experimental music. Pierce proved remarkably tolerant of Klüver’s art-and-technology efforts, seeing these as activities that could benefit engineers as well as artists. One also senses Pierce’s conviction that supporting such interdisciplinary efforts was something an internationally renowned organization like Bell Labs should do. Throughout the 1960s, buoyed by AT&T’s profits, the lab supported a small coterie of artists-in-residence, such as Nam June Paik, James Tenney, Lillian Schwartz, and Stan VanDerBeek.[20] Many of the tools and devices that Klüver and his engineering colleagues worked with daily were later absorbed into the art-and-technology movement. These included lasers—a fertile new area of research at Bell Labs that Klüver joined—as well as microelectronics, television and video systems, computer-generated speech, wireless signal transmission, and even the manufacturing technology used to make inflatable communication satellites. “I had colors on my palette,” Klüver recalled, “that nobody else had in New York. I had Bell Laboratories at my disposal.”[21]

Being a division of AT&T, most of Bell Labs’ research was necessarily directed toward communication technologies. But the lab’s staff and managers interpreted this so expansively that it was conceivably easier to list areas that Bell Labs’ researchers *weren’t* engaged in. Klüver found himself working amid an extremely talented cohort with backgrounds ranging from psychology and acoustics to physics and computer science.

AT&T's Cold War-driven profitability provided its engineers with the security to pursue opportunities in esoteric areas that lacked an immediate commercial payoff or to things that, to an outsider, might seem to have little to do with engineering per se. For example, Bell Labs employed Arno Allan Penzias and Robert Woodrow Wilson, two radio astronomers interested in microwave radiation. In 1964, they started experimenting with a specially designed antenna at Bell's research facility in Holmdel, New Jersey. Originally built to pick up radio wave transmissions bouncing off passive communications satellites, the faint static Penzias and Wilson detected in 1964 was interpreted as the 13.7-billion-year-old background radiation from the Big Bang. Wilson and Penzias shared the Nobel Prize in Physics in 1978 for their serendipitous finding, a discovery partially enabled by Bell Labs' tolerance, even encouragement, of research activities which appeared to have little to do with telephones.[22]

In 1965, Pierce wrote an article for *Playboy* that told the magazine's readers about how researchers were using computers to do things other than solving equations or collating data. Focusing on his colleagues' experimental forays into art and music, Pierce (with Klüver providing background information) presented a lively "portrait of the machine as a young artist."[23] Pierce himself had already been making computer-generated music for several years with fellow engineer Max Mathews. Mathews, who directed the lab's Acoustical and Behavioral Research Center, had also helped program an IBM computer to sing the song "Daisy Bell (Bicycle Built for Two)" (this composition later appeared in Stanley Kubrick's film *2001: A Space Odyssey* when HAL 9000, the homicidal computer, mournfully plays this tune as it is deactivated). Bell Labs tolerated, if not encouraged, this eclectic work because of its potential applications for electronic speech synthesis, a topic that would interest any communications company.

One of the more intriguing anecdotes Pierce shared with *Playboy*'s readership was an experiment that Bell researcher A. Michael Noll had recently conducted. Using a computer and microfilm plotter, Noll created an image very similar to Piet Mondrian's 1917 painting *Composition with Lines*. Noll then asked Bell Labs' staff to try and differentiate between the original and his version. Only 28 percent correctly identified the Mondrian and, when questioned further, almost 60 percent said they preferred Noll's computer-generated image (it later won first prize in a contest sponsored by the journal *Computer and Automation*).[24] Still, Pierce confessed he felt compelled to ask, "It's fascinating but is it *art*?"

Video artist Nam June Paik, who spent time at Bell Labs as an artist-in-residence, already had his answer: “If you are surprised with the result,” he later told an interviewer, “then the machine has composed the piece.”[25] Paik and Klüver were already acquainted with each other. The Korean-born artist had even prepared a *Sonata quasi una fantasia for Billie Kluver*, an essay of sorts in which he proposed “some utopian or less utopian ideas and phantasies.” Referencing Klüver’s own professional research, Paik asked, “Can the laser, so-said breakthrough in electronic [sic], become also the breakthrough in art?” After noting that “someday every high-brow will have a laser phone number” that “enables us to communicate with everyone everywhere wirelessly and simultaneously,” Paik advised his friend to “please, tele-fuck!”[26]

Klüver, inspired by his conversations with Paik and other artists, advised Pierce that computers, lasers, and the like were akin to a “glorious new paint.” Judging what computers and their programmers produced would have to wait until “preconceived standards of what we think art is” had time to properly adjust. For the moment, Klüver suggested that “the best definition of what art is is implicit in Marcel Duchamp’s work: A person calls himself an artist. He makes an object which he calls art. Others come and look and agree that the object is art.”[27] Klüver’s disinterest in delineating “art” from “technology”—or adjudicating good art from bad—would become central to E.A.T.’s strategy of ignoring aesthetic judgments in favor of supporting the collaborative process itself.

Klüver had continued thinking about the social life of technology and the purported cultural divide between artists and engineers after he started working at Bell Labs. Like many educated people, Klüver followed the debate Snow’s two cultures lecture provoked. “I reacted very strongly against it,” Klüver recalled, “I didn’t feel he had the right to divide society into two separate cultures.” Nonetheless, one important aspect of Snow’s diagnosis resonated strongly with the engineer: “It was his call for action to bridge the gap that I subconsciously agreed with.”[28] For Klüver, this translated into getting directly involved with the contemporary art scene around him.

PART OF THE MACHINE

On the evening of Saint Patrick’s Day in 1960, in the Museum of Modern Art’s courtyard some 250 invited guests shuffled their feet in puddles of cold slush while waiting to watch a work of art destroy itself. The artwork in question was Jean Tinguely’s *Homage to New York*, a contraption some twenty-three feet long and twenty-seven feet high and painted more or less white. One critic described it as an "object of bizarre attraction if not of classical beauty."[29] Less charitable people might have looked at *Homage*, with its bicycle wheels, bottles, and upright piano, and seen the result of an encounter between a hardware store and a landfill. Indeed, many of *Homage*'s parts had come from Lower East Side junk shops and outer borough dumps.

After a long delay, the audience—which included Governor Nelson Rockefeller, a throng of art critics and artists, uptown glitterati, and three television crews—watched *Homage* noisily clank its way toward destruction. The piano mechanically played three forlorn notes. Smoke provided by a mixture of ammonia and titanium tetrachloride placed in a bassinet drifted toward the audience. An overheated resistor lit a candle sitting on the piano's keyboard. A radio turned on and the machine poured some gasoline on itself. A scroll with the words "Yin is Yang" unfurled. The smoke turned yellow and the piano was soon ablaze while artist Robert Breer filmed the damage. A money-throwing machine, concocted by Robert Rauschenberg and primed with gun powder, went off in a flash, scattering silver dollars across the museum's sculpture garden. The piano collapsed, the performance ended, and a few curious guests spirited away bits of *Homage* as souvenirs before its remains were carted back to the dump. Almost all that remained of the event were memories and pictures.[30]

Klüver joined the *Homage* project after Pontus Hultén told his friend that Tinguely would be having a show in New York. When the engineer met the artist, Tinguely described for Klüver a machine that would destroy itself in front of an audience. Over the next few weeks, Klüver and Tinguely foraged throughout the city for industrial detritus and then assembled *Homage* underneath a geodesic dome in the museum's garden. Tinguely had planned *Homage* as a series of spontaneous events that the machine would carry out. To build electrical circuits that would trigger these actions, Klüver brought in Harold Hodges, a technician from Bell Labs. Hodges had joined the lab in the 1950s, working with physicists on projects such as building lasers and light-emitting diodes. Compared to what Hodges's "day job" required, Tinguely's technical needs were elementary but, as Klüver and he came to appreciate, they still were beyond the scope of the average artist.[31] To make *Homage*'s piano collapse, for instance, Hodges embedded a resistor in solder material that melted at low temperatures. When Tinguely closed the circuit, the resistor would overheat, which, in Rube Goldberg fashion, would cause the piano's support to give way. That was the plan anyway. During the actual performance, Breer cautiously approached the collapsing contraption and gave it a helping shove. This was all fine to Klüver.

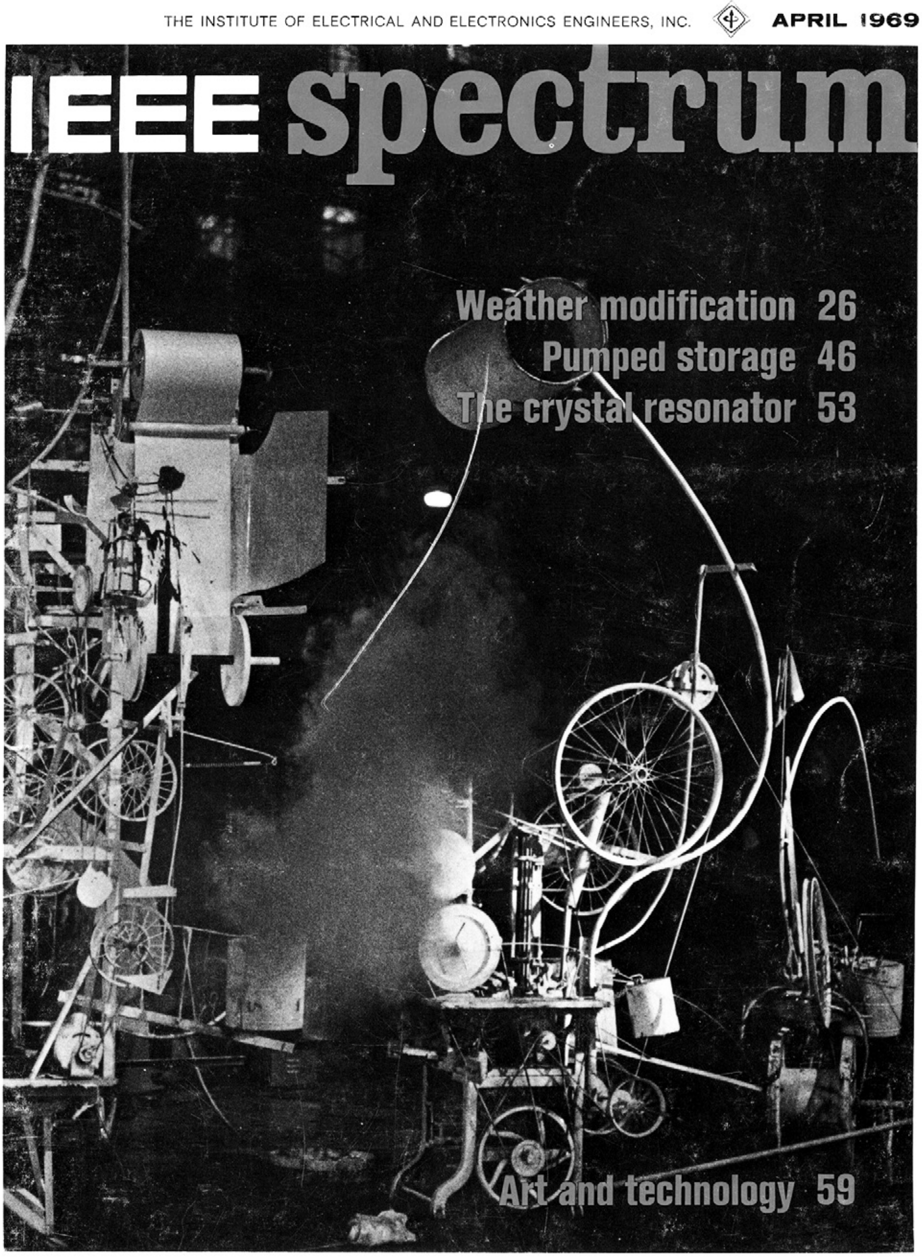

Figure 3.2 Jean Tinguely's *Homage to New York*, made in 1960 with assistance from Klüver, as shown on the April 1969 cover of *IEEE Spectrum*. While the work of art itself was remarkable, just as striking was its appearance on the cover of a magazine read almost exclusively by electrical engineers.

"All good machines destroy themselves," he told a writer from the *New Yorker*, "the machine doesn't have to work."[32] Indeed, he would argue, it was through technological failures—such as power blackouts—that people could learn more about the built environment around them.

As articles about *Homage* appeared in city newspapers, Klüver worried that his participation might reflect poorly on Bell Labs. He was, after all, a professional engineer who had helped build a system designed to fail spectacularly. But when he arrived at work the morning after *Homage* fell to pieces, John Pierce only asked why he hadn't been on the guest list. In any case, John Canaday, a newly hired art critic for the *New York Times*, ignored the engineers' contributions and focused only on the artist (a pattern that would occur frequently during the art-and-technology wave of the 1960s). Canaday, often critical of the still-central school of New York-based abstract expressionism, was delighted by *Homage*, branding it "a legitimate work of art as social expression."[33] He also praised Tinguely, whom he portrayed as a descendant of the 1920s Dada movement, for managing to get something so experimental into MoMA's courtyard in the first place. *Homage* was an "elaborate witticism" that expressed a "gesture of independence against the machines" via a "preoccupation with destruction.[34] Not all critics agreed. At the *Nation*, *Homage* simply was an expression of modern decadence. "A garden party," their critic lamented, "This is what protest has fallen to in our day."[35]

Inspired by the *Nation*'s negative response, Klüver prepared his own essay titled "The Garden Party." For those people inclined to critique *Homage* on the basis of whether it worked perfectly—and it certainly didn't—the engineer explained they missed the point. In fact, had it worked properly, *Homage to New York* would merely have reflected the perfection of a "purely technocratic society," and not the realities of the urban environment. Klüver insisted that just "as a scientific experiment can never fail, this experiment in art could never fail." In the coming years, Klüver and other participants in the art-and-technology movement often repeated this point of view. After he became the chief spokesperson for E.A.T., Klüver insisted that the essential experiment was collaboration itself and not what resulted from it. In the final analysis, he noted that Tinguely, inspired by the possibilities technology offered, had asked engineers for help in realizing his vision. "As an engineer, working with him," Klüver concluded, "I was part of the machine."[36]

A few months after *Homage*'s self-destruction, Hultén asked Klüver for help recruiting American artists for a new exhibit called (in English) "Art in Motion."[37] The Swedish curator imagined this as a sequel to the 1955 "Le Mouvement" show at Denise René's Paris gallery. Klüver, increasingly uninterested in his engineering research at Bell Labs, gladly accepted Hultén's offer. Over the next several weeks, the two Swedes drove around the East Coast collecting works of kinetic and movement-related art for Hultén's show. At Naum Gabo's studio in Connecticut, for example, they recorded the artist reading from his 1920 "Realistic Manifesto" before loading one of the Russian artist's kinetic works into Klüver's car. Alexander Calder contributed a model for an unrealized motorized piece he called *The Four Seasons*, which Hultén replicated at full size for his show. Likewise, a reproduction of Marcel Duchamp's famous piece, *The Large Glass*, was made with the artist's approval. Works from other established artists such as László Moholy-Nagy filled out Hultén's show while Klüver secured contributions from younger American artists he knew. By the time he was done, about two dozen Americans, including Robert Breer, Jasper Johns, and Robert Rauschenberg, contributed to Hultén's exhibition. Meanwhile, Hultén, who wanted to showcase movement as a creative force in twentieth-century art, solicited works from European artists (Frank Malina contributed three lumidynes).

Hultén's "Art in Motion" show proved important for the Moderna Museet's reputation.[38] Just as the film societies he and Klüver were involved with a decade earlier had helped introduce Stockholmers to experimental cinema, the exhibition showcased new avant-garde artists for Swedish museum-goers.[39] One result was that Hultén encouraged Klüver to continue to seek out more works by rising New York-based artists. By the end of 1961, Klüver, when not at Bell Labs, was roaming New York galleries and collecting pieces for Hultén. One of his finds was Robert Rauschenberg's now-famous *Monogram*. Made between 1955 and 1959, it merged painting and sculpture by incorporating a rubber shoe heel, a tennis ball, and—scandalously to some 1960-era viewers—a large stuffed angora goat encircled suggestively by an automobile tire.

A different Swedish connection led to Klüver helping organize a major modern art exhibition in the United States. Hans Nordenström was an experimental filmmaker and cartoonist Klüver knew from his university days. After Klüver helped get some of his friend's sketches published in the *Village Voice*, he was contacted by a curator in Philadelphia. Audrey Sabol was interested in purchasing one of Nordenström's cartoons and agreed to meet Klüver in New York. Sabol arrived with her colleague, Joan Kron, with whom she was planning a show of established American painters in Philadelphia. By the time they had finished their drinks, Klüver had persuaded the two curators to organize an exhibition featuring younger and more experimental New York artists.

In addition to works by Robert Rauschenberg and Jasper Johns, Klüver promised them pieces from fellow Swede Claes Oldenburg, who would soon become one of the leading figures of the 1960s art scene, as well as works by James Rosenquist and George Segal. "Art 1963: A New Vocabulary" opened in Philadelphia as one of the first shows devoted to what English critic Lawrence Alloway later christened "pop art."[40] Modest-sized (and confusingly named as it took place in late 1962), the show helped ignite a boom of interest in the new style. Influenced by images from mass media and the presence of everyday objects, pop artists claimed deep affinity for Marcel Duchamp who, after decades of relative detachment from the art world, was reemerging as a major influence on artists such as Andy Warhol, Rauschenberg, and Johns.

Duchamp's work also had a great impact on Klüver. The engineer recalled how a 1959 monograph about Duchamp hit the New York art world "like a bomb." Robert Lebel's book emphasized Duchamp's long-standing interest in technology—the artist was in the audience when Tinguely's machine committed mechanical suicide—but also noted his irreverence toward the traditional knowledge that scientists and engineers employed in their work.[41] As Lebel saw it, Duchamp wanted to strain the laws of science and thereby help people see how scientific principles were "unstable to a degree."[42] In his essay for the "Art 1963" catalog, Klüver, echoing Duchamp, wrote that he too feared the "consequences of a science which is built on concepts like symmetry, invariance, uniqueness, time, and beauty" alone. Instead, he delighted in the possibility that science and engineering might also "create surprise, nonsense, humor, pleasure, and play" for people.[43]

This might seem a somewhat unusual view, especially for someone based at an organization where unfettered scientific research underpinned so much of its success. But, as Klüver saw it, scientists worked in an inherently theoretical and abstract world. However, this idealized arena was often incompatible with the hands-on, physical nature of what artists actually did. Klüver decided that the most productive pairings would not be between artists and scientists but between artists and *engineers*. These were the people he believed interacted daily and directly "with the physical world." Consequently, Klüver insisted that engineers, with their command of technology, were the community most relevant for artists.[44] "'Art and science' has a feeling of fakery to me," he told one art historian, "Art cannot contribute anything to science as I see it."[45]

In September 1962, Klüver proposed that Bell Labs start an association to "establish direct contact" between "working artists in the New York area" and the laboratory's staff. Artists, Klüver said, had recently become "very interested in science and engineering." Many of their "technical problems and dreams" could be easily solved by research staff if they only had the chance to learn about art and the artists' work. In return for their contributions, the lab's technical staff might discover "new possibilities" for their own work, an allusion to the possibility that artists' experiments might contribute somehow to corporate profits and patents. Ultimately, Klüver imagined the club as a means to "narrow the gap between 'The Two Cultures' that C. P. Snow has decried and which could hardly find a better representation," he noted, than the distance between Bell employees and artists working just across the Hudson River.[46] Although it got no traction with Bell Labs' management, Klüver's short proposal contained the core ideas that later found expression in E.A.T.

Soon after the "Art 1963" exhibition opened, Klüver was in Washington, DC for an electrical engineering conference. He took time off to drop by the Washington Gallery of Modern Art, a small operation near Dupont Circle that curator Alice Denney helped launch in 1961. Klüver offered to drive her to Philadelphia to see the show he had helped put together. Inspired by the blossoming enthusiasm for pop art, Denney and the Jewish Museum's Alan Solomon organized their own exhibition they called "The Popular Image."[47] Klüver's contribution was to borrow a reel-to-reel tape recorder from Bell Labs and interview participating artists. After Klüver edited the tapes, Columbia Records issued a limited edition album featuring the conversations. To go with the albums, Andy Warhol and Klüver silkscreened custom covers emblazoned, pop art-style, with "Giant Size $1.57 Each" that were displayed at the show's opening.

If C. P. Snow wanted an actual example of someone whose professional and personal life concurrently crossed cultural divides, Klüver offered an ideal model. During the day, he might be conducting engineering research with lasers and writing technical reports and patent materials for Bell Labs. During evenings and weekends, Klüver attended Happenings and gallery shows that informed the essays he composed about the New York art scene. His activities outside of Bell Labs also enabled Klüver to meet actress and model Olga Adorno. When they married in 1964, Warhol threw a glitzy party for the couple at his Factory studio.[48] The next step in Klüver's self-conscious fashioning of himself as an effective bridge between communities of artists and engineers was to get involved with making art himself.

"A GHOST BOUQUET OF POSSIBILITIES . . ."

In terms of engineering, Klüver's contributions to Tinguely's *Homage to New York* were modest, in large part because the artist's vision didn't require that the technology actually work as planned. Tinguely, in fact, was quite unbothered when its parts and systems failed. It was through the *Homage* project that Klüver met Robert Rauschenberg and the two men soon started their own collaborative effort, but with more stringent parameters.

Rauschenberg's initial idea was to create some sort of interactive environment in which a viewer would trigger changes in smell, lighting, or temperature.[49] For him, this was an extension of his earlier mixed media pieces with which he sought new ways to "get the room into the picture."[50] At first, Rauschenberg incorporated static objects like light bulbs or radiometers. But his plan for a new piece, eventually called *Oracle*, really started to come together after Klüver gave him a tour of Bell Labs in 1961. As the artist later told critic Barbara Rose, seeing all those new technologies was "like being handed a ghost bouquet of possibilities."[51]

Rauschenberg, after conferring with Klüver, decided to build an audio environment. Its core would be five AM radios whose volume and stations were controlled by a single electronics unit. Rauschenberg was attracted to the idea of radios, with their "endless changes of information" as opposed to fixed images, and he had already experimented with them. For example, his 1959 piece called *Broadcast* included three radios, concealed behind the canvas, with exposed knobs viewers could use to tune in various stations. There was a random element too, as moving one knob might make all three radios change station or volume.

At first, Rauschenberg envisioned *Oracle* as five large painted canvases with a control unit situated in front of them. The technical challenge for Klüver was that the artist wanted no visible wires running between the control box and the paintings. In addition to the wireless requirement, Rauschenberg also wanted elements of unpredictability, such as having radios skip between stations at variable speeds and change in volume. To help solve this problem, Klüver again recruited Harold Hodges. With "midnight requisitions" from Bell Labs, Klüver and Hodges assembled a system where radios, their speakers removed, would be mounted in a central control unit. They would then wirelessly retransmit to a system of receivers, amplifiers, and speakers located behind each of the painted panels. However, interference from the homemade transmitters produced a hideous cacophony of noise that the engineers couldn't easily fix at first.

Work on *Oracle* proceeded in fits and starts over a few years. Rauschenberg dropped the idea of painted panels and decided to incorporate the radio system directly into a five-part sculpture. Klüver's schedule was increasingly busy with organizing art shows while the artist was heavily in demand after he won the Venice Biennale's

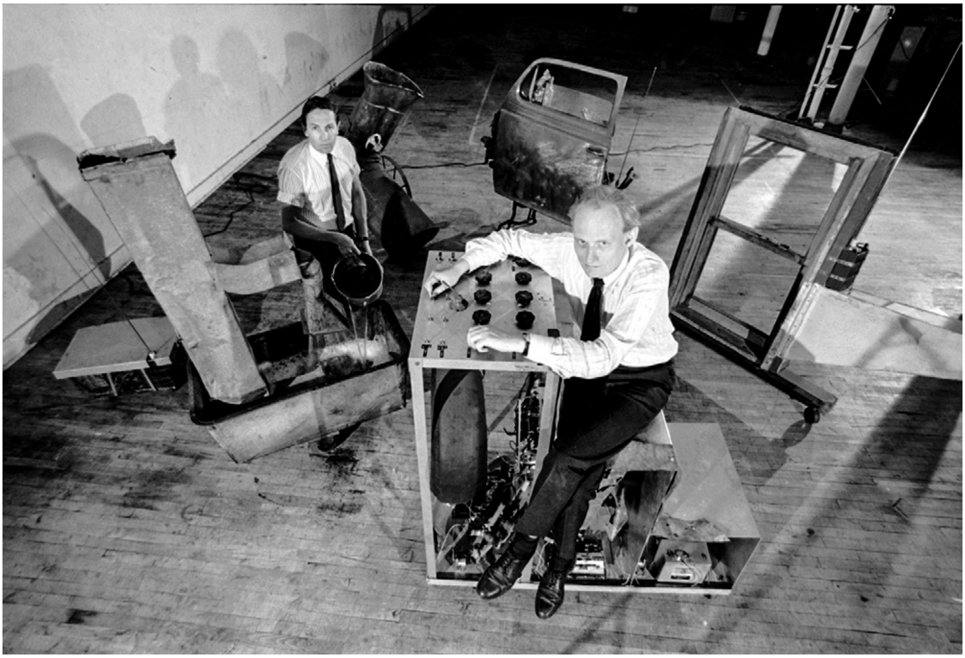

Figure 3.3 Billy Klüver and Robert Rauschenberg, ca. 1965, working on *Oracle*. Photo by Yale Joel/ The LIFE Picture Collection via Getty Images.

grand prize in June 1964. In his spare time, Hodges devised an ingenious system using a small motor, running at a variable speed, that could scan across the AM band. But Rauschenberg's request for a wireless system continued to stymie the two engineers. Then, in the summer of 1964, technology caught up with them. Commercial products using transistors—a device invented at Bell Labs—were becoming increasingly affordable, Klüver and Hodges discovered a company that made a transistorized wireless microphone system that avoided the noise and distortion of their previous setup.

Rauschenberg, meanwhile, selected the eclectic objects he wanted for *Oracle*. These included a car door, a cement-mixing tub on wheels that he transformed into a fountain, and an aluminum staircase, where Klüver and Hodges concealed the electronics. As he worked with the artist, Klüver came to understand that many of his selections—where receiving antennae were placed, the size of knobs and speakers—were "esthetic choices . . . arbitrary from an engineering point of view." Rauschenberg meanwhile learned about unfamiliar tools and saw how the technical challenges *Oracle* posed "were not part of the engineers' normal daily problem-solving agenda as set by the corporate environment."[52]

Rauschenberg first displayed *Oracle* in May 1965 at the Leo Castelli Gallery, located in a stylish townhouse on 77th Street. Visitors could freely walk among the work's sculptural elements and experience the sonic environment the engineers had created. The sound from the radios varied as bits of talk, music, static—loud, soft, clear, or distorted—transformed and merged with the sound of flowing water from the tub-as-fountain. The overall sensory impression was the sights and sounds encountered while walking around a busy city neighborhood on a hot summer's day with apartment windows open to the street.

Rauschenberg was not the only visual artist Klüver collaborated with in the mid-1960s. He also helped Jasper Johns integrate neon lights into two paintings. Like Rauschenberg, Johns wanted no visible wires. Accordingly, Klüver and Hodges repurposed a rechargeable battery to provide high voltage for neon letters in *Zone* (1962) and *Field Painting* (1964). Wireless technology also appealed to Andy Warhol and he asked Klüver to build a floating light bulb. After some calculations, Klüver concluded that batteries for it would be too heavy for a helium-filled balloon. However, he learned about a new material recently patented to preserve food for the military. Klüver showed the delicate silvery material to Warhol who then had a different idea. When the packets were filled with helium and heat-sealed, the floating metallic pillows became Warhol's *Silver Clouds* (1966).

Klüver's network of collaborators expanded to include experimental dancers and composers. His primary entrée to this community was through an avant-garde group that started operating in the early 1960s out of the Judson Memorial Church in Greenwich Village.[53] The leaders of this liberal Baptist congregation saw arts patronage as commensurate with their social activism. As a hotbed of creative activity, the Judson Dance Theatre brought together up-and-coming artists and dancers with more established people like Rauschenberg, Merce Cunningham, and John Cage. Many Judson members had worked previously with Cage and Cunningham and, once E.A.T. was active, they became steady contributors to the new organization.

In 1963, for example, Klüver collaborated with dancer and choreographer Yvonne Rainer for a piece she called *At My Body's House*. Like many members of the Judson cohort, Rainer sought to redefine the boundaries of dance. For her piece, Rainer wanted the audience to hear the sound of her breathing as she performed, so Klüver helped make a small radio transmitter for her to wear. A contact microphone on her throat relayed a signal to it and then sent it to speakers located in the performance space.

Around the same time, Klüver and a small group of engineers from Bell Labs built an even more technically sophisticated system in collaboration with Cunningham and Cage. *Variations V* was designed as an exploration of the codependence of movement and sound. As its title indicates, the piece was one in a series of works invoking "indeterminacy" that Cage started to make in 1958. Over time, Cage's compositions began to incorporate mediums other than music with greater complexity. *Variations V*, for example, featured experimental films by Stan VanDerBeek and manipulated television images by Nam June Paik projected onto screens behind Merce Cunningham's dancers.

Klüver and the engineers he recruited built a complex and interconnected system of electronic sensors. For example, there were photocells, the light beams of which the dancers would break as they moved about the stage. Cage's composition also called for the placement of several tall antennae around the stage. Robert Moog, an engineer who later became famous for his audio synthesizers, designed these to be distance-sensitive to performers' motion, much like how a theremin worked. When a dancer approached one of them, it registered the person's proximity as well as the intensity of light incident on the photocell built into its base. The engineers fed this information into a sound system along with input from multiple tape machines and short-wave radios. All of this affected the output of the sounds and musical passages Cage had composed, which the audience then ultimately heard through loudspeakers in the concert hall.

In July 1965, Cage presented *Variations V* at the Philharmonic Hall in New York with engineers joining the performers on stage to operate the equipment. During one performance, Cunningham, dressed in red pants and a gray shirt, pedaled a bicycle through the ensemble of sound and light detectors, triggering what Allen Hughes, a theater and dance critic for the *Times*, termed a "symphony of the visual and aural banalities of our age." Hughes deemed the entire show "monumentally successful" and speculated that, by giving dancers near-instant control over the light, film projections, and sounds, the artists and engineers provided a "glimpse into an extraordinary theatre of the future."[54] In its scale and technical complexity, *Variations V* presaged even more ambitious efforts Klüver would undertake with fellow engineers and the artists.

Klüver was, of course, intimately familiar with the engineer's working world and the aspirations, anxieties, and professional sensibilities shaping it. Time spent collaborating and socializing with members of the New York art scene afforded him insights into artists' profession as well—what art critics labeled as the "sensibility of the sixties."[55] The perception (and self-perception) of artists—like that of engineers—was rapidly transforming. Most notably, the stereotype of the poor, brooding, solitary artist emoting his feelings all over the canvas—the postwar evolution of Jackson Pollock from icon to cliché offers the obvious example—had diminished if not disappeared entirely. "There are," painter Gene Davis said, "few starving Gauguins today unless they are dedicated masochists." In fact, the sudden rise of stars like Warhol and Rauschenberg suggested that artists could become well-off celebrities. This was not to say that artists were comfortable with their newfound status. "Although the artist is now being feted," critics noted, "there is the suspicion that his works are being consumed rather than understood." Or, as Davis framed it, the "measure of success, for too many, has become the number of press clippings, not the work of art."[56]

Klüver's friend Allan Kaprow observed that the professional artist in the mid-1960s was fast becoming "a man of the world."[57] "If the artist was in hell in 1946, now he is in business," he wrote; "they [artists] are indistinguishable from the middle-class from which they come." And just like "personnel in other specialized disciplines and industries in America," artists were increasingly concerned with prosaic things like buying life insurance, paying their bills on time, and sending their kids to college. Professional degrees were increasingly de rigueur, replacing the self-taught acquisition of skills and knowledge and leading Kaprow to conclude that young artists were "almost all college educated," a trend engineers were quite familiar with as well.[58] The size of the "art world" expanded noticeably during the 1960s, offering another parallel with the Cold War engineering community. With increased social respectability came financial security and perhaps even fame, as the "vanguard artist is sought after in the homes of the wealthy" and courted by the nouveau riche who increasingly saw art as aesthetically and financially rewarding. (Only a few years earlier, *Fortune* magazine had identified modern art as a good financial investment.) As Kaprow, a keen-eyed observer of his professional community, saw it, a new species of creative person was now "hurrying along Madison Avenue and jetting around the world, alternately clinking glasses at receptions and conducting seminars" while making art "soberly and steadily, for there is not a moment to lose."[59]

Kaprow's depiction of artists with traits and ambitions similar to other professional, middle-class strivers is remarkable in that they so closely resembled attributes of the engineers and scientists working in industrial laboratories. For many scientists, doing research had become less and less that of a moral calling. Instead, "artist" and "researcher" were increasingly seen as vocations that offered financial security and status acquired by accomplishment and university degrees.[60] Indeed, as Kaprow noted, artists were increasingly joining the ranks of engineers and scientists as "men of the world" (with everything else that gendered term entailed for both communities in the 1960s).

At the same time, artists such as Frank Stella and Andy Warhol assumed new creative roles that more closely resembled middle managers and corporate executives, positions to which engineers were often promoted. And just as the arrival of pop art and other 1960s-era movements eroded the stereotype of the penurious artist working alone in his studio, the portrayal of *where* art was made also changed. Warhol's decision to designate his industrial loft as the "Factory" carried significant symbolism.[61] The professional identity and modes of working for both engineers and artists was changing and even converging. Likewise, just as engineers found satisfaction in working with others, many artists increasingly engaged in collective art making, the Judson Theatre being just one example.[62]

Artists and engineers alike worked amid what economist John Kenneth Galbraith had christened just a few years earlier as "the affluent society." Beyond the increased possibility of economic security that some individual artists experienced, this translated into improved public support for the arts in general. Just as engineers benefitted from federal investment in science and technology, a new infrastructure emerged in the 1960s to support artists. Besides the growing number of academic appointments for artists, states and private philanthropies devoted more money to the arts. Standing foremost in terms of public visibility was the establishment of the National Endowment for the Arts in 1965. Although funded at a pittance compared with behemoths like NASA, the NEA's creation reflected the era's concern with fostering creativity and a belief that the arts offered another means to enhance national prestige. Although artists expressed varying degrees of suspicion about federal patronage, painter Adolph "Ad" Reinhardt noted that while "government sponsorship of art is ugly," the "absence of government sponsorship of art is uglier."[63] Like engineers, the artist "produces a much-sought-after product . . . and expects to cut himself a sizable piece of the fiscal pie."[64]

As public interest and patronage for art blossomed in the 1960s, new publications reporting on contemporary art appeared in established redoubts like New York and Paris as well as emerging scenes like Los Angeles.[65] For example, *Artforum* started in San Francisco in 1962 as a venue for articles about contemporary art. The magazine moved to Los Angeles three years later before eventually relocating to New York.[66] In London, *Studio International* likewise reported on the art world's current trends.

These magazines, along with longstanding publications like *Art in America* and *Art News*, sometimes praised and often critiqued the art-and-technology movement in both the United States and overseas.

Given the media attention successful artists received, and the attendant profits and patronage that art could generate, some people asked whether a true avant-garde scene even existed anymore. Sculptor James Wines saw the avant-garde, along with "the Establishment" and the audience for art as all part of "one congenial alliance." In this changing environment, Wines said, art was increasingly "taking its cue from science." Another sculptor observed that "scientistic jargon and space analogies" had now become part of "everybody's tool kit."[67] These new possibilities excited many artists. As Kaprow evocatively put it, "John Glenn may have caught a glimpse of heavenly blue from the porthole of his spaceship, but I have watched the lights of a computer in operation. And they looked like the stars."[68]

Critic Barbara Rose viewed the resurgence of interest in technology not as a source of creative inspiration, but as a "mine for materials and techniques." Using these resources productively would require securing information, access to facilities, and know-how. "The problem," Rose concluded, was "how to allow the artist to get out of the studio and into the factory." One solution she suggested was "some sort of match-making liaison between artists and industry."[69] This was exactly the need Klüver envisioned Experiments in Art and Technology meeting.

Although most artists and engineers still saw themselves as members of two separate cultures, their professional communities shared more than just passing similarities. The 1960s were, as one historian framed it, an "age of contradiction" when "great aspirations for a new society" encountered profound uncertainty as to how to best instigate desired social and political changes. This was foregrounded against experts' predictions of an approaching "postindustrial age" in which the intellectual and informational, not the industrial, realm would assume greater importance.[70] This imagined future would increasingly rely on the "capacity of society to call forth creativity" in innovative ways. And in this coming postindustrial era, artists and engineers alike would direct their work less toward the making of *things* but instead gravitate toward *processes* where collaboration and interdisciplinarity were essential components in soldering together a new creative community.[71]

4

POWERING UP

> We need a house full of exotic technology.[1]
>
> Billy Klüver, 1966

Years after the vitriol toward *9 Evenings: Theatre and Engineering* had dissipated, Billy Klüver wrote a polite yet pointed letter to Calvin Tomkins. The engineer and the *New Yorker* writer had known one another since Tomkins profiled artist Jean Tinguely in 1962. Although Tomkins had explored the contemporary intersection of art and technology in several, generally favorable, essays, it was his new book on the career of Robert Rauschenberg, titled *Off the Wall*, that provoked Klüver.

"Tad," Klüver wrote, "You persist in perpetuating the myth that *9 Evenings* was an 'engineering failure.'" Instead, Klüver countered, Tomkins should have emphasized the electrical innovations and technical ingenuity displayed during the performances. Tomkins disagreed, noting that it was Klüver's own engineering colleagues who had complained about the technical foul-ups that bedeviled several performances. But the two men agreed on one thing. The artist-engineer collaborations of *9 Evenings* represented, as Tomkins said, "an important event in the history of the period."[2]

As its subtitle indicated, *9 Evenings* combined a type of theater—a multimedia fusion of dance, music, film, sculpture, and the visual arts—with engineering. It marked a transition from smaller, more individualistic efforts of the sort that Frank Malina and Billy Klüver had initially engaged in, toward expensive and highly visible

Figure 4.1 Herb Schneider, Robert Rauschenberg, Lucinda Childs, Leonard J. "Robby" Robinson, Per Biorn, and Billy Klüver discussing the Theatre Electronic Environmental Modulator (TEEM) system in preparation for *9 Evenings: Theatre and Engineering*, Berkeley Heights, New Jersey, 1966. Photo attributed to Frances Breer. Photograph Collection, Robert Rauschenberg Foundation Archives, New York.

projects built around much larger artist-engineer collaborations. As Tomkins noted, *9 Evenings* signaled "the beginning of a movement" that would inevitably "generate great interest among contemporary artists."[3] Today, archival boxes filled with press releases, newspaper copy, radio show transcripts, and even a book manuscript speak to how *9 Evenings* captured the art world's attention.[4] It was out of the crucible of *9 Evenings* that Experiments in Art and Technology emerged.

Despite the publicity it received in the fall of 1966, *9 Evenings* rarely garners more than a wisp of a recognition today in conventional narratives of the era's art history. Likewise, most historians of technology have overlooked the places where their own interests intersect with art making in the long 1960s. In contrast, for the smaller community of scholars who study the emergence of new media and the digital arts, what happened inside the 69th Regiment Armory in October 1966 stands as a formative antecedent for later attempts to integrate artists and art with engineers and technology.[5] However, *9 Evenings* is often framed in teleological terms as a key moment that led inexorably to today's digital arts culture. In contrast, this chapter explores *9 Evenings* both on its own terms as well as how it represented a change in strategy for Klüver and his colleagues in their quest to bring artists and engineers together.[6]

Almost all of the scholars who have explored *9 Evenings* have focused their attention on the artists and their art. This probably would have not displeased Billy Klüver. As the engineer explained to the readers of *Artforum* in 1967, he decided early on that *9 Evenings* should give "no special emphasis" to the technologies that made artists' performances possible. This was done, Klüver said, to prevent the artworks from being misunderstood by the public and art critics as merely "technically interesting" entertainment.[7]

But the fact remains that they *were* technically interesting. And, for a professional community often stereotyped as taciturn (to the point of being papyrophobic) when asked to record their thoughts and feelings, engineers' recollections of *9 Evenings* are actually quite extensive. In reports, memos, and after-performance surveys, they candidly detailed their failures, frustrations, and successes. Accompanying these stacks of written material were films and an extensive photographic record, which give a sense of the performances and the preparations leading up to them. As one of the most carefully and self-consciously documented art-and-technology events, the signal strength of *9 Evenings* captures our attention. And regardless of art critics' narratives of *9 Evenings*, the participating artists certainly saw Klüver's engineering colleagues as equal and essential collaborators in an interdisciplinary creative process. As one engineer who participated in *9 Evenings* said, what Klüver put in motion amounted to nothing less than a highly visible effort to "prove C. P. Snow wrong" by splicing together two professional groups who previously had little to do with one another.[8]

"TELL THEM WHAT YOU HAVE . . ."

In 1965, Klüver likened his career to a "man standing with one leg each on an ice float. The ice floats are drifting apart and I shall end up with the fish." To help reconcile his bifurcated professional identity, Klüver received permission from his supervisors at Bell Labs to write a short book for his engineer and scientist colleagues. It would explain, Klüver proposed, how engineers working together with artists could expand the perspectives of both communities. These collaborations could reveal something new about technology and perhaps also "open up a new field of activity for the engineer."[9] A colleague who read the proposal—Klüver intended to call the book *Engineering in Art* with composer John Cage writing a foreword—praised the project, saying it "should help close the gap between the 'two cultures.'"

Despite securing his employer's approval, Klüver soon abandoned the project. Instead, he decided it would be more efficient to directly engineer social situations that would bring different professional communities together. "Only by making new inventions which are not conditioned by ordinary attitudes," Klüver later said, "can we learn about technology."[10]

He started by inviting artists out to the New Jersey suburbs for informal tours of Bell Labs. Alex Hay, a young artist who also worked as Robert Rauschenberg's assistant, made one of these pilgrimages. Hay was especially struck by Klüver's revelation that any researcher whose experiments didn't fail a significant percent of the time "was not considered a good scientist." Failed experiments, the engineer explained, could be as instructive as successful ones, and, at Bell Labs, they were simply an accepted part of the research process.[11] This neutral stance toward outcomes, established from the outset, became a hallmark not just for *9 Evenings* but E.A.T.'s activities for years to come. Properly done, experiments meant risk and came with the possibility of both disappointment and enlightenment.

In the fall of 1965, Klüver decided to launch an experiment that would bring artists and engineers together on a scale larger than what he had already orchestrated. As often was the case, Klüver's initiative linked back to Sweden. In November 1965, his artist friend Öyvind Fahlström connected him with Knut Wiggen, director of Fylkingen, an organization in Stockholm devoted to experimental music. Wiggen's group was planning a festival for art and technology in Stockholm in September 1966 and, after talking to Klüver, offered a spot on the program for American artists.

To get things moving, Klüver convened a small meeting at Bell Labs. The artists included composers John Cage and David Tudor; dancers and choreographers Steve Paxton, Lucinda Childs, and Deborah Hay, as well as her husband Alex; and Robert Rauschenberg. Later, choreographer Yvonne Rainer and Fahlström himself joined the lineup. Klüver's supervisor, John Pierce, also came to the first gathering as did Max Mathews and Herbert A. Schneider, a specialist on wireless broadcasting. Just as Klüver's colleagues were well acquainted with one another, the artists had worked together several times. For example, Deborah and Alex Hay were making plans with Steve Paxton and Robert Rauschenberg for a series of performances called *Five Choreographers in Three Dance Concerts* that would take place in Los Angeles.

But this familiarity only went so far and Klüver was nervous as the two groups appraised one another. "The air was stiff," he recalled, and their conversations soon soared off into abstract musings. As he wrote in his diary, "What are we doing at 13,000 feet? It's a long walk to earth." Pierce brought their speculative dialogue back to terra firma. "Tell them what you have," he encouraged his engineers, "tell them about things."[12]

Judson member Simone Forti—who at the time was married to *9 Evenings* participant Robert Whitman—kept detailed notes, including tape-recorded interviews, throughout the project.[13] At first, she observed, the artists started to propose unrealistic ideas for what they might do if given access to enough technology and engineers' know-how. For example, Steve Paxton asked whether Bell Labs' engineers could devise a "method of discovering where people are looking." Rauschenberg asked if one could pass electricity between performers like "pocket lightening," or if engineers could transmit invisible television images. Deborah Hay proposed choreographing dancers and remote-controlled carts. Almost all of these suggestions—Rauschenberg's desire to float through the air, notwithstanding—were possible, the engineers said, but they might not be practical. But such "fantasies," Forti observed, served as an initial "meeting ground for two groups of people who didn't yet know how to work together."[14]

One of Klüver's first priorities was establishing an effective mode of collaboration between the engineers and artists. This did not come easily, or quickly. A few engineers, like Harold Hodges and Cecil Coker, had already worked with artists. But most of Klüver's colleagues found the initial meetings disorienting. Several engineers were surprised at how open-ended the artists were about their goals even as the weeks went by. However, Jim McGee, who normally did research at Bell Labs on holography, realized that "the artists are not thinking as vaguely as they give the impression of doing." Getting his colleagues to be generous with their time was something that also concerned Klüver. As Hodges, only half-jokingly, asked Forti, "What's the motivation for doing this before fixing my lawn mower?"[15] Nonetheless, by the end of *9 Evenings*, Hodges had volunteered some 250 hours. Presumably, his yard suffered accordingly.[16]

Identified in newspaper stories simply as "engineers," the thirty or so of Klüver's colleagues who joined the project were diverse in skill sets, though not so in race and gender. Some of the men had recently earned PhDs in physics while others were technical assistants with less formal education but decades of research experience at Bell Labs. As a group, they possessed expertise ranging from systems engineering and computer science to wireless transmission, mobile telephone design, and laser physics. Few of them knew much, if anything, about contemporary art. Engineer Leonard "Robby" Robinson joked, "When I first heard we were going to Rauschenberg's, I thought it was a Jewish delicatessen. That's how much I knew about art."[17]

A failure to communicate was a key issue in Snow's diagnosis of what separated the two cultures. From the start of Klüver's planning, he anticipated that the project's success would depend on how much and how well the artists and engineers established a rapport across this divide.[18] Herb Schneider, who would assume the task of integrating the various electrical systems for *9 Evenings*, wrote "When artist meets engineer, each stalks the other like an animal of another species."[19] A few researchers suggested that artists propose their ideas and then leave the execution to the technical experts. This, however, was not the collaborative dynamic Klüver envisioned. Especially frustrating to the engineers was getting artists to express their ideas in "sufficiently concrete terms" so that they could design and build the necessary equipment. "The artists live with their ideas for so long," engineer Dick Wolff recalled, "they had a visual image of what they wanted but failed to fill us in on the details."[20] And, of course, for the engineers, the devil was in those details.

The two communities also had different patterns of working. "The artist," Schneider said, "must realize that the engineer solves his problems not by gross changes in direction," but by iteratively moving toward a resolution, something the engineer likened to "a mouse in a maze."[21] For many artists, maintaining flexibility for as long as possible was part of their creative process but this trait tested the patience of engineers who had to convert their concepts into real-world hardware and electrical wiring. At the same time, Klüver insisted that the actual engineering underpinning the art remain unobtrusive and elegant so that the audience would "not look for gimmicks."[22]

Klüver steadfastly believed that the entire effort constituted a type of experiment, even a new form of doing research. As a result, the premise for what became *9 Evenings* was less about making art or doing theater. Rather, Klüver and the other participants came to understand it as a creative exercise to see whether artists and engineers could work together.[23] To have any hope of success, the artists needed to display an "extraordinary amount of patience with the slow rate at which an engineer proceeds." And the engineers "had to deal with the vagueness" of artists who were still learning about the possibilities presented by new technologies. Klüver likened the commitment required to "lifting yourself by the hair." As he told reporters, "If you don't do it all at once, it does not work."[24]

One of Klüver's main tasks involved its own form of painful hair pulling: fundraising. The art-and-technology festival originally planned for Stockholm was going to be very expensive. By the time *9 Evenings* was over, in fact, its costs had soared to more than $160,000 (some $1.2 million today) making it one of the most expensive art projects of the era.[25] To raise funds, Klüver and Rauschenberg approached corporations and philanthropic organizations, as well as individuals. The Rockefeller Foundation, for example, was in the process of expanding its support for the arts.[26] Klüver proposed that artists who worked with engineers could generate an altogether different understanding of technology and, in the process, "society may get an invaluable by-product." Just as the work of scientists "inspires technology and makes it grow," he told one of Rockefeller's officers, so to could artists' experiments.[27] As he saw it, university departments were too conservative, so the resources to support the kind of experimentation he envisioned would have to come from the business and philanthropic worlds.

Although Klüver's appeal to the Rockefeller Foundation was unsuccessful, he and Rauschenberg eventually secured about $50,000 from individual sponsors. Typical donors included New York-based art collectors like Robert and Ethel Scull, who also bankrolled an art gallery in Manhattan, and art patrons Dominique and John de Ménil. A few business owners, including Seymour Schweber, an art collector whose electronics company was prospering in the 1960s, also responded to Klüver's sales pitch. "I feel art, the theatre, and engineering will never be the same after the show!" Schweber said, "Let's change the world."[28]

As he courted donors, Klüver was advised by Walter K. Gutman, a stock market analyst, art collector, and avant-garde filmmaker from New York. Klüver pitched the Swedish festival as an opportunity to bring technology "out of its hiding" and show that it was "not limited to what the engineers say it is." As opposed to the "conservative McLuhanites" who had a "technology-the-big-terror-has-to-be-put-to-service" attitude, Klüver described his group's goal as "making new inventions" that were "not conditioned by ordinary attitudes" about how society viewed technology.[29] From this experimentation, a new creative culture could emerge.

Over several meetings, the artists outlined an ambitious array of different technologies and visual effects they wanted to experiment with. These included an infrared television system, elaborate audio devices with wireless transmission of sound and signals, and a "floating form which follows a person" that artist Fahlström was especially excited about. Klüver also proposed a television show, sponsored by AT&T, that would be broadcast simultaneously from New York and Stockholm. "Such a program would make artistic use of [the company's] most important means of communication," Klüver told John Pierce, while sending a "genuinely positive and nonpolitical" message.[30] The television program didn't materialize—in the 1960s, AT&T kept a low profile as the Federal Communication Commission scrutinized its business practices—but the idea of communication at a distance, as we'll see, inspired parts of the artists' performances.

By the spring of 1966, the Stockholm festival was taking shape. In addition to lectures from John Cage, Buckminster Fuller, and Pierce, a series of dance, music, and theater performances would be given over a weeklong period. The artists' open-ended approach, however, began to stoke anxiety among Klüver's Swedish partners, who didn't necessarily share his enthusiasm for an expensive and relatively unscripted public experiment. Moreover, the Swedes viewed the engineers as minor partners in the collaboration, to the point of asking Klüver why they even needed to be in Stockholm for the festival. Klüver and the artists were understandably discomfited at the thought of presenting complex, technology-based performances without proper engineering support and, more importantly, were unwilling to make the engineers anonymous and invisible technicians. "I like our organic collaboration," Rauschenberg said, "where technique and aesthetics are both being experimented with rather than our having a set aesthetic to implement with technology."[31] Moreover, Klüver and his group were uninterested in performances that attempted to glamorize technology or make it seem beautiful. Sweden was then in the midst of building its modern welfare state. So, to Klüver, the festival offered an opportunity to "stimulate disorder" and, to the growing concern of his hosts, perhaps "increase the entropy of such a perfect society."[32]

In response to mounting tensions between the Americans and the Swedes, Klüver dispatched a legal advisor to Stockholm with a list of outstanding issues to be resolved. These ranged from budgetary items and ownership of equipment to the artists' request to have the festival's program presented as edible waffles on paper plates. Culinary demands aside, the Swedes were puzzled about how to promote a festival when the artists still couldn't provide much more than nebulous descriptions of their work.[33] The artists and engineers, meanwhile, thought the cautious Swedes didn't appreciate the exploratory nature of their collaborative experiment.

A flurry of letters, opinion pieces in Swedish newspapers, and legal-looking agreements circulated that summer amid rumors that the Swedes might attempt a Solomon-like resolution by offering contracts to just a few individual artists. Ironically, the Swedes were getting cold feet just as the festival was "becoming very hot copy" for reporters and art writers.[34] *Life* was in the midst of preparing a major photo essay about the emerging art-and-technology movement that would feature Klüver, for example. When the Stockholm project finally fell apart, Klüver's artists and engineers were unclear if they had jumped or been pushed off. But now, after months of planning and equipment design, they suddenly had no laboratory in which to carry out their experiment.

In late July, Klüver sent a hasty telegram to John Cage and David Tudor, who were touring abroad (and who the Swedes had approached about breaking ranks). "No festival. We fought hard but no chance," he wrote, but "Good chance festival to be held in New York early October in Armory. Same show same cast." A few days later, Klüver received a brief reply: "Refusing Stockholm. Accepting Armory."[35] The experiment would continue.

COLD WAR THEATER

Since 1906, New York's 69th ("Fighting Irish") Infantry Regiment had operated out of an armory on Lexington Avenue in midtown Manhattan. Although one of several such military structures in the city, for art enthusiasts, the massive three-story building, with its distinctive and deeply recessed arched facade, was simply *the* Armory. Its notoriety had been secured in 1913 when it hosted the "International Exhibition of Modern Art." Spectators were thrilled and scandalized by European and American works with styles ranging from fauvism to futurism.[36] In August 1966, when *Life* published its feature article about art and technology, it noted that Klüver's festival would now happen in the exact same place where Americans first saw Duchamp's cubist painting *Nude Descending a Staircase*.[37] Historical importance aside, the size of the Armory appealed to Klüver's artists who decided to gamble and "go big because that was more exciting and dangerous." Their decision also was tied to an intuition that future collaborations with engineers would necessarily make "full use of the mass media and industrial resources" and be "big in scale."[38] At a time when large telescopes, space probes, and particle accelerators reflected a "Big Science-style" of research, perhaps Klüver's team was unconsciously following suit.

The Armory presented the artists and engineers with an intimidating arena. Its great hall, with 33,000 square feet of floor space, was capped by an arched roof some 130 feet high.[39] Several thousand people could easily fit inside. The space appeared, as one critic noted, "frightening to anyone except a regiment—a vertically sliced barrel arching over like a gigantic Nissen hut."[40] When Öyvind Fahlström first viewed the interior, he was impressed not just by the immense size but also by a giant crimson banner proclaiming in gold letters: "Never Disobeyed an Order. Never Lost a Flag." But the Armory had not been designed with theatrical performances in mind. The engineers from Bell Labs who first ran an experimental sound test discovered a lengthy reverberation lasting several seconds. "The space itself was beautiful," Forti noted, but "the place was like an echo chamber. You couldn't get a coherent sound."[41] Engineer Robby Robinson, when asked what problems the Armory presented, recounted simply, "Space, communications, dirt."[42]

The shift from Stockholm to New York prompted Klüver and his colleagues to reconsider the event's name. "Art" and "technology" were vague terms, they decided, that didn't truly represent what they wanted to accomplish. "The name of the performances at the Armory came out of long arguments about what we were doing," Klüver recalled, "the day 'Art and Technology' was left behind was a day of relief for everyone."[43] The subtitle, *Theatre and Engineering*, was both more specific and gave audience members familiar with avant-garde Happenings an idea of what to expect. The choice of words also highlighted the melding of professional communities who would be making it all possible.

Reporters and art critics who wrote about *9 Evenings* in 1966 tended to direct their attention to the individual performances of the ten artists involved. I want to take a different, yet complementary approach, focusing more on the technologies that enabled these performances. Although each artist's creation was unique, they often shared equipment with one another, giving a sense of behind-the-scenes overlap. Seeing the individual devices and gadgets that engineers built as part of a larger scheme—one based on cutting-edge technological systems in which Bell Labs was deeply invested—also suggests a broader pattern of invention and innovation that was at work.

Art critic Lucy Lippard labeled *9 Evenings* as "total theatre," while the *Reporter*, a monthly news magazine published by Bell Labs, called it "switched-on theatre."[44] But, given the nature of the technologies developed for *9 Evenings*, one could just as easily have called it "Cold War military-industrial theater." Almost all of the engineers and technicians Klüver recruited for *9 Evenings* worked at facilities in the Bell Labs system. And, at its peak in the mid-1960s, about 40 percent the company's personnel worked on military projects, such as the Nike missile system, and AT&T was one of the biggest recipients of Pentagon contracts.[45] The engineers who volunteered for *9 Evenings* had plenty of expertise—lasers, microelectronics, acoustics, and wireless transmission—applicable to defense projects. And, of course, research and development at Bell Labs helped advance AT&T's larger corporate goal of improving and expanding the company's global communications network.

By mid-1966, organizing *9 Evenings* was consuming more and more of Klüver's time. Although still a member of Bell Lab's technical staff, his research and patenting activities declined even as he accepted more invitations to speak about art and technology. Klüver took extraordinary care to emphasize the voluntary nature of the contributions from him and his fellow engineers. For instance, he instructed the public relations firm hired to promote *9 Evenings* to stress that "in every connection where Bell Labs is mentioned, it must be stated that this is a free time occupation."[46] Even so, it was entirely possible that "somebody will find the spare time activities of the people involved strange." "What would happen," he wondered, "if somebody invented something useful?"[47]

Why did Bell Labs' managers allow Klüver and his colleagues to join a project that ultimately consumed hundreds of hours of company time? Several years after *9 Evenings*, Klüver's boss, John Pierce, explained his tolerant attitude as a matter of preserving the lab's reputation. "I said the people in my division who were involved," he recalled, "could work on this because it was important that it not fail completely." Pierce even went so far as to ask managers in other departments at Bell Labs for extra help as the opening date for *9 Evenings* drew closer.[48] AT&T's monopoly power and profitability enabled this freedom, creating an environment where engineers could collaborate with artists without drawing too much disapproval from their managers. The company, routinely high on the Fortune 500 list, took in nearly a quarter of a billion dollars of profit in 1966 alone. With "two cultures" tropes providing rhetorical justification, strong corporate earnings and a thriving national economy helped enable the art-and-technology movement.

ENGINEERING THE ELECTRIFIED ARTIST

Throughout the planning for *9 Evenings*, Klüver and the other engineers designed a wide range of devices and pieces of equipment to help realize the artists' larger aesthetic visons. As the two groups continued their dialogue, several common themes emerged in terms of what the artists wanted to accomplish. For instance, more than a few artists expressed an interest in "revealing the invisible." An excellent example of this is *Grass Field*, created by artist Alex Hay in collaboration with Herb Schneider, an Austrian-born engineer who specialized in mobile radio and telephone systems. Central to Hay's vision was his wish to capture and project the sound of his biological activity. "I want to pick up faint body sounds like brain waves, cardiac sounds, muscle sounds and amplify them," he told Simone Forti.[49] The name Hay gave his performance was a clever play on words. While the piece would reveal his own body's electric fields, "Grass" not only referenced the pastoral—a contrast to the engineers' world—but also the Grass Instrument Company, which made electroencephalograph (EEG) equipment for medical and lab uses.[50]

Methods for sensing and recording the body's electrical signals dated back to the nineteenth century when physicians first chronicled the heart's activity. But detecting EEG signals and rendering them audible for a public art performance presented the engineers with several challenges. EEG equipment is not usually mobile, for example, while Hay's concept for *Grass Field* required batteries and amplifiers small and lightweight enough so the artist could still move about. Engineer Robby Robinson—like Schneider, he also specialized in mobile communication technologies—eventually used compact integrated circuits, a recent innovation, to build a suite of small amplifiers that picked up signals from Hay's heart, brain, and eye muscles and relayed them to an FM wireless transmitter. Schneider, meanwhile, consulted with experts at local hospitals to learn more about optimizing EEG procedures.[51]

Hay's views toward his collaborators changed markedly while making *Grass Field*. Even though he thought engineers still had "very conventional ideas about art," their willingness to creatively solve problems impressed him. For instance, Hay originally found Cecil Coker, a specialist in speech synthesis technology, to be "pretty casual and apathetic" toward his project. But, as *9 Evenings* drew closer, he saw Coker "working as much at night as in the day." Robinson meanwhile turned into an energetic "ball of fire," Hay noted, who spent his own money to buy electronic gear for the artist.[52] Gradually, the engineers transformed Hay's body into an instrument where machinery and human were connected so as to convert biological information into electrical signals and audible output.

The engineering for *Grass Field* continued right up to opening night as engineers shuttled equipment between Bell Labs and the Armory. When the engineers first attached amplifiers to Hay's body, they received unstable signals that would not produce the "elusive sounds of the body" Hay wanted. The general consensus was that *Grass Field* would probably have to be canceled. But, after a final push by Robinson, Schneider, and the other engineers to troubleshoot the equipment, Hay was happily surprised when he showed up at the Armory and found working equipment that could generate the "beautiful set of sounds" he wanted.[53] As the engineers helped Hay suit up for his performance, Robinson likened it to "preparing a man to go into space."[54]

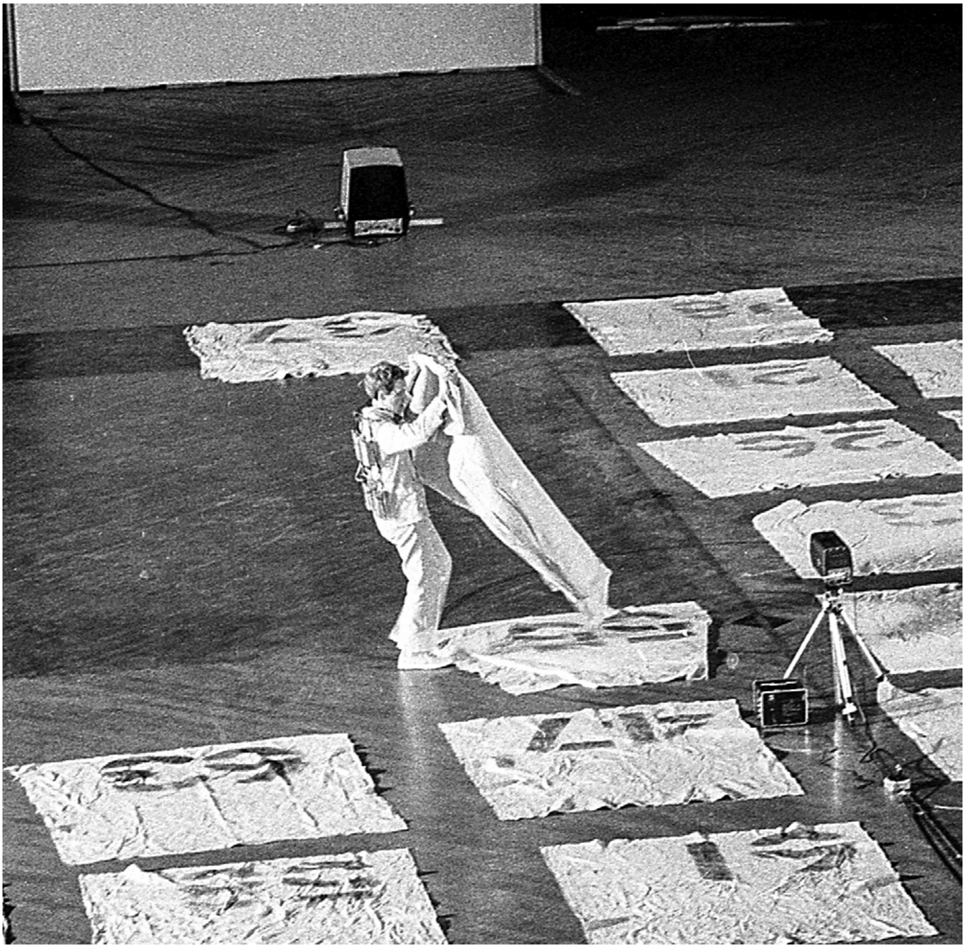

Figure 4.2 Detail showing Alex Hay performing *Grass Field* with the miniaturized equipment that Herb Schneider, Robby Robinson, and other Bell Labs engineers designed and built. Image courtesy the Klüver/Martin Archives (photographer unknown, all rights reserved).

Lucy Lippard described how Hay appeared wearing a "peach-flesh pyjama suit" with wires running from his head and down his back, all the electronics and sensors his work needed discreetly conveyed in a small, backpack-size rig. He then meticulously laid out 100 squares of peach-colored cloth on the Armory floor. When finished, Hay sat down in front of the audience and the lights dimmed. A giant screen behind him "projected a close-up image of his expressionless face" as he calmly opened and closed his eyes. All the while, the small amplifiers picked up and transmitted the sounds of his body. Then Robert Rauschenberg and Steve Paxton came out and systematically picked up the squares until *Grass Field* ended with the cloth restacked in front of Hay.[55]

Robert Rauschenberg took a different approach to revealing and projecting the unseen. His performance began as a tennis match on the Armory floor between artist Frank Stella and professional tennis player Mimi Kanarek. The rapid miniaturization of electronics, driven by Cold War imperatives, allowed Bell engineers to install tiny, custom-made microphones and radio transmitters into their rackets. These picked up vibrations and, via an antenna wrapped around the racket's head, relayed the signals to speakers around the Armory, which the audience heard as a loud, reverberating, metallic sound. Rauschenberg's piece called for these sounds to gradually switch off the Armory's giant ceiling lights until the game ended in total darkness. Then, as a sound recording of the tennis game was replayed, a second act unfolded. Several hundred volunteers, recruited by Rauschenberg from the local community, silently walked on stage, unseen in the dark. Infrared cameras linked to a television system projected their ghostly images onto large screens, allowing the audience members to see them in the dark. Following cues from Rauschenberg, the cast members carried out basic instructions, such as "draw a rectangle in the air" or "hug someone quickly." Then the house lights gradually came on and the cast members stopped moving, before the lights went out once more to signal the piece's end.

Although no one attending the Armory show could have known it, Rauschenberg's concept for *Open Score* indirectly resembled a secret military project that was just getting started thousands of miles away. In 1966, the Department of Defense initiated a new effort to disrupt supplies and troops moving southward along the Ho Chi Minh Trail. Christened Operation Igloo White, it employed a complex network of sensors to create an electronic picket line that could detect enemy motion, noise, and body heat. All this information was collected and relayed to a central command center, which alerted attack aircraft, some equipped with infrared cameras, and directed them to their targets.[56] Some of the sensors deployed for Igloo White were designed by engineers at a classified laboratory managed by Western Electric, a manufacturing company that also supplied equipment to AT&T.

Although none of the engineers associated with Rauschenberg's piece worked on Igloo White, the equipment used for *Open Score* suggests the extent to which *9 Evenings* relied on similar Cold War-derived technologies. Larry Heilos, an engineer at Bell Labs experienced with industrial photography, recalled how hard it was to find "good infrared equipment" that wasn't "classified by the US government." In the end, a small New Jersey company provided him with cameras made by a Japanese company. Thinking that they might also use lasers that projected in the infrared, Heilos helped develop a heat sensitive phosphor that would react to this otherwise invisible light.[57] Klüver often referred to this invention, along with the small wireless amplifiers developed for *9 Evenings*, as proof that art-technology collaborations could benefit corporate patrons.

On the last night of *9 Evenings*, when he performed *Open Score* for a second time, Rauschenberg added an unexpected and entirely untechnological third act. He walked onto the darkened stage carrying a cloth sack with Simone Forti bundled inside. A spotlight followed them about while she sang a haunting Tuscan love song. With Forti's clear and unaltered voice providing a human counterpoint to the stacks of high-tech electronics around her, the engineers marveled at the sudden improvisation. Herb Schneider remarked that they could have easily rigged a system to electronically broadcast Forti's voice. But then the performance, he realized, "would not have been a Rauschenberg."[58]

Given the participation of experimental composers John Cage and David Tudor with engineers from a company specializing in telecommunications, it's not surprising that electronic soundscapes appeared in *9 Evenings*' pieces. Tudor, for instance, designed his performance, titled *Bandoneon! (A Combine)*, around a traditional Argentinean musical instrument that had been electronically modified. (The composer included the exclamation mark as the mathematical sign for a factorial, not a grammatical emphasis.) As Tudor played his accordion-like instrument, lighting effects and television images were be projected onto screens. The composer added more technological complexity with loudspeakers and other equipment mounted on radio-controlled carts that moved about the Armory as he performed. Several microphones picked up sounds from Tudor's bandoneon. These signals, in turn, passed through a series of electronic devices.

One of these was a sixteen-channel Proportional Control System built by Fred D. Waldhauer. Born in Brooklyn, Waldhauer had earned his engineering degree from

Figure 4.3 Bell Labs engineer Fred Waldhauer with equipment during the rehearsals for *9 Evenings: Theatre and Engineering*. Waldhauer's Proportional Control System is on the table in the center foreground. Image courtesy the Klüver/Martin Archives (photographer unknown, all rights reserved).

Cornell in 1948 and then worked on transistor circuitry for RCA before joining Bell Labs in 1956. Even as a student, New York's art and music scenes fascinated Waldhauer. A photo from the late 1940s shows the young engineering student posing with saxophonist Charlie Parker at a club in New York, where the engineer also regularly attended modern art shows.[59] At Bell Labs, Waldhauer researched the simultaneous digital transmission of multiple telephone calls, a system AT&T introduced in 1962 while he was earning an advanced degree from Columbia University. An in-house magazine that Bell Labs published had first alerted Waldhauer to Klüver's interests and he became one of the most articulate and active advocates for the art-and-technology movement.[60]

Waldhauer built his system around a small plotting board covered and divided into sixteen white plastic squares. As he described in a technical memo for Bell Labs, each of the squares contained a light sensitive photoresistor that was linked to a separate electronic channel. By moving a light pen over the board, a person could control audio speakers and theater lights in real time or use it to trigger a series of preprogrammed effects. Essentially, Waldhauer's device acted, as he described it, as a remote-controlled instrument that gave artists "control over auditory and visual aspects of an environment such as a theatre."[61]

Signals from the microphones wired to Tudor's musical instrument also passed through another device called a Vochrome. It was built by Robert Kieronski, a twenty-five-year-old Bell employee who had just earned his BA in electrical engineering from Lehigh University. The Vochrome converted analog music from the bandoneon into an electronic signal. Kieronski's name for his instrument harkened back to a famous piece of equipment built in the 1930s by Bell engineer Homer Dudley. Dudley's Vocoder electronically analyzed and synthesized sounds, most notably the human voice, and was used during World War II to encrypt high-level Allied voice communications.[62] To build his Vochrome, Kieronski salvaged reeds from a pipe organ and isolated them in a soundproof box. Microphones inside Tudor's bandoneon mechanically vibrated them—imagine a series of tuning forks—when he played certain musical notes. This, in turn, produced electrical signals that triggered other electrical circuits.

These devices added their own unpredictable color (albeit in a "somewhat chaotic fashion") to the original notes Tudor played.[63] His instrument had a cutoff button that would instantly mute all sounds so that the audience would just hear the architectural resonance of the performance space. When Tudor performed *Bandoneon!*, a team of well-dressed engineers joined him on stage to oversee the electronic systems for him. "As David played a certain note, one light would become brighter or dimmer in response to the volume of the tone," Herb Schneider recalled, "and the Armory responded with [its] sound. It would be feckless to suppose that it could be described in words."[64] Tudor was, in effect, playing not just the bandoneon but the Armory itself.

Where Tudor wanted his piece to transform analog music into digital signals, Lucinda Childs, a twenty-six-year-old dancer and choreographer, wanted to convert her bodily motions into sound. For an aesthetically and technically complex piece she named *Vehicle*, Peter Hirsch, an acoustics engineer at Bell's military-oriented Whippany facility, designed a "Motion Music Machine." Akin to sonar systems Bell engineers built to detect submarines, this machine emitted pulses of high frequency sound, which the audience couldn't hear.[65] When these sound waves encountered a moving object—such as Childs's large, red buckets purposefully swinging from a scaffold—they were reflected back to the receiver, mixed with the original signal, converted into audible sounds, and broadcast throughout the Armory. The effect was a distorted swishing noise Klüver likened to "wind blowing through a forest."

Danish-born engineer Per Biorn, whose research at Bell Labs concerned semiconductors, also worked on Childs's *Vehicle*. Biorn was first drawn to *9 Evenings* when he read about Klüver's contributions to Tinguely's *Homage to New York*. Its self-destruction-by-design seemed the antithesis of what professional engineers were trained to do. Art-and-technology collaborations, where randomness was tolerated, even encouraged, seemed like "engineering turned upside down" to the curious Biorn.[66] Dick Wolff, who normally researched superconducting materials at Bell Labs, recalled a demonstration of a television camera he gave to artist Robert Whitman. Whitman was intrigued to see that the television monitor retained an image from bright objects even after the camera's focus had moved on. Wolff explained that they could easily fix this problem with a better image tube but Whitman "was very excited," preferring the long residual imagery. "To predict this would happen is very difficult," Wolff reported to Klüver, "and as far as an engineer is concerned, I would never have guessed it."[67]

Like David Tudor's *Bandoneon!*, chance and unpredictability were essential elements for John Cage's piece. Cage's father was an electrical engineer and prolific inventor and the composer himself had briefly worked on technical projects in the 1930s before turning to experimental music.[68] With *Variations*, the multimedia series he started in 1958, Cage combined randomness with the digital exactitude of electronics technology, some of it provided by Klüver. For *Variations VII*, Cage's contribution to *9 Evenings*, the composer added a new element that intrigued some artists in the 1960s: telepresence.

Telepresence—the technologically mediated experience of being elsewhere—was something Bell Labs engineers were very familiar with.[69] One could argue that AT&T's entire raison d'être was based around creating a sense of being present in a distant place. Early advertisements for telephone service emphasized how AT&T's technology brought friends and family into the same virtual space.[70] The company debuted its "Picturephone" at the 1964 New York World's Fair while Bell Labs helped build a globe-spanning network of communication satellites. As more Bell engineers joined *9 Evenings*, Klüver asked John Pierce about the possibility of further experimenting with telepresence using technologies unique to their lab. "The artists have increasingly been asking about the possibility of making use of Telstar," he reported, "or some transatlantic TV communication."[71]

Figure 4.4 Composer John Cage in the Armory with the ten telephones installed for his *Variations VII* piece. Photo by Robert McElroy/Getty Images.

For *Variations VII*, Cage wanted to bring distant sounds to the *9 Evenings* audience. For this, New York Telephone installed ten dedicated phone lines in the Armory. (The actual phones were kept locked away once people discovered they could make free, long-distance calls with them.) Cage then chose several locations in New York that he would call during his performance and, via open phone lines, capture "those sounds which are in the air at the moment of performance" and share them with the audience. These ranged from Merce Cunningham's dance studio and the press room of the *New York Times* to a German restaurant in Union Square and the aviary at the Bronx Zoo. People listening received a sense of eavesdropping remotely on a distant place. During one performance, an engineer inadvertently added to the indeterminacy by hanging up one of the phones, a mistake that didn't bother the composer at all.

Where Cage wanted to provide a sense of being someplace distant, two other pieces for *9 Evenings*—Yvonne Rainer's *Carriage Discreteness* and Deborah Hay's *Solo*—approached telepresence via technologies of remote control. Both women were dancers and choreographers who knew Klüver via the Judson Dance Theatre. Hay designed her piece around eight radio-controlled carts operated by formally dressed performers who were "conducted" in real time by composer James Tenney. Controlled by FM radio signals, the carts provided platforms for some dancers to pose on while, as the piece progressed, Hay and Olga Adorno performed a series of dance gestures. Rainer took an even more direct approach to remote control for her work, the engineering of which Per Biorn supervised. Lit by a spotlight in the Armory's balcony, where she could view the performance area, Rainer radioed directions to an ensemble of performers below. As they carried out her instructions, images and video clips—James Cagney's face (he had once appeared in a film based on the 69th Infantry Regiment) or W. C. Fields juggling cigar boxes—would be intermittently projected onto two screens.

All of the performances engineered for *9 Evenings* exemplified what artist Dick Higgins had branded as "intermedia." With their blend of sound, light, photography, film, dance, and sculpture, they formed part of "an uncharted land that lies between collage, music, and theatre."[72] Perhaps the work that most epitomized this was Öyvind Fahlström's *Kisses Sweeter than Wine*. Lasting more than an hour and a half, the narratively intricate piece was also the only performance that offered any direct social commentary on technology and politics. Fahlström's notation for the work included "robot-like people" who could internalize vast amounts of data or carry out complex calculations even as their narrow technical capabilities placed them at risk.[73] *Kisses Sweeter than Wine* also called attention to America's deepening involvement in Southeast Asia by including a character playing a Vietnamese barber and a monstrous looking bust of President Lyndon Johnson with a hole in its head.

Harold Hodges, Fahlström's lead engineer, helped build the piece's most dramatic effect—a thirteen-foot, remote-controlled craft made of Mylar that circled inside the Armory when the piece was performed. Fahlström called this an "anti-missile missile," a pun of sorts given Bell Labs' two decades of work on the Nike antiaircraft missile system. In addition to television, film, and slide projections, a platform bearing a scantily clad "Space Girl" descended from the ceiling. To this seemingly bizarre ensemble, he added "snowflakes" that fell upward, an effect Hodges ingeniously created using helium bubbled through a soap solution. In Klüver's estimation, Fahlström's piece posed the "most complicated" scenario for the engineers among a host of already complex pieces.[74] Altogether, the ten different compositions that made up *9 Evenings* required the construction of some two dozen different electronic devices. As opening night drew closer, controlling the complexity of all this gear presented a problem of its own.

A SYSTEMS SOLUTION

In the 1960s, business writers often referred to a seemingly abstract entity called the "Bell system." This was shorthand for the company's sprawling, still-expanding technological footprint of world-class labs, networks of telephone lines, satellites, microwave relay towers, switching centers, manufacturing firms, and local operating companies all overseen by tens of thousands of people. As the twentieth century unfolded, engineers had increasingly taken a systems-level approach to managing such complexity. With its origins in large-scale military projects, enthusiasm for systems management reached a peak in the mid-1960s as both the Apollo program and the Vietnam War placed a premium on all-inclusive thinking.[75] Given the popularity of what became known as "systems thinking," as well as the ways in which their professional careers were oriented toward maintaining vast electronics and communication networks, it's no surprise that the engineers of *9 Evenings* adopted a similar strategy at the Armory.

The ensemble of electronics that they had designed and built was what Klüver christened as the "TEEM." An acronym for "Theatre Electronic Environmental Modulator," Klüver branded it "our most ambitious undertaking."[76] The idea was that the TEEM would function as an adaptable control system for an entire set of performances, "fulfilling the requirements of the ten artists' specific theatrical situations." By the time the engineers had finished building what art writer John Gruen called a "small masterpiece of electronic invention," it consisted of nearly 300 different components, all designed to enable the "simultaneous remote control of multiple sounds, lights, and movement of objects" from a single location in the Armory the engineers began calling "Central."[77] If we imagine the performers as aircraft, Central and the TEEM were akin to an airport control tower.

For instance, almost all performances employed a set of transistorized "encoders" and "decoders." The former would generate a tone—think of the sound heard when you pick up the telephone—that the decoder then responded to. The wireless receivers and transmitters, meanwhile, that were part of the larger TEEM system operated essentially as tiny FM radios. Legally using them, however, required an experimental radio license from the Federal Communications Commission, a process AT&T executives and New York's Senator Jacob Javits helped facilitate. In their FCC application, the engineers described their plan to carry out an electronics "experiment" as "an adjunct to a non-radio research study involving technological expressions of art forms."[78] With approval secured, Klüver enthused that "putting radio in the theatre" would be "the crown of the whole thing," boasting that "there's nothing like it on the market."[79] All told, Klüver estimated the equipment built by Bell engineers cost some $20,000 (or about $150,000 today).[80]

The artists first had the chance to see this ensemble of devices in early September at a rented high school gymnasium near Klüver's house. Although not all the artists fully understood the technical intricacies of their gear, they certainly appreciated the complexity their engineer collaborators were grappling with. Bell Labs' engineers were taking tools, concepts, and professional experience derived from working on intricate and often convoluted systems and using these to tame the unruly devices essential to *9 Evenings*. David Tudor approvingly recalled how the engineers, in helping realize the artists' often abstract visions, had totally "bent the concept of systems engineering," reshaping it from the traditional purposes to which it was applied.[81]

Herb Schneider soon realized, however, that despite extensive dialogue, the two groups still lacked sufficient clarity as to specific details, desired effects, and how to accomplish them. To help bring order to a situation about to veer out of control, Schneider turned to a familiar engineering tool. He created a series of technical diagrams, one for each artist, showing the hardware connections between the devices that would be on the stage or out of the audience's view in the control booth.[82] After the group finally moved into the Armory in early October, his detailed drawings

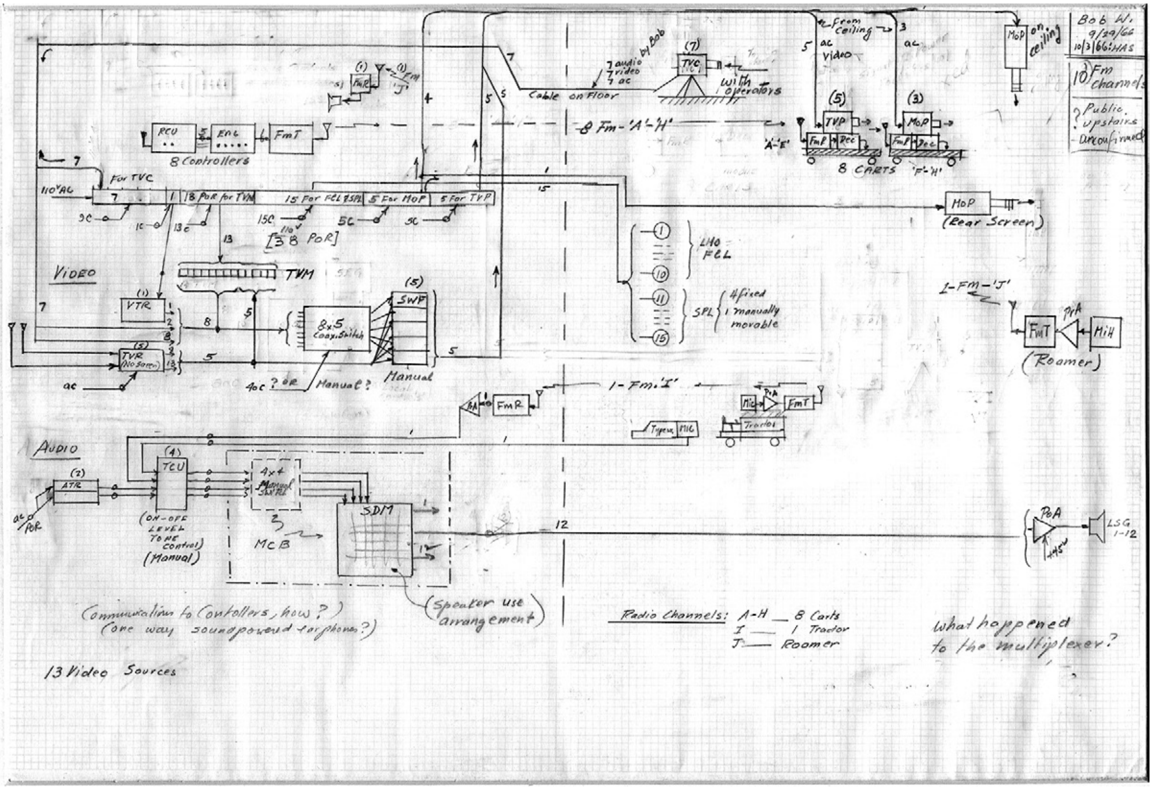

Figure 4.5 Engineer Herb Schneider's schematic drawing for Robert Whitman's *Two Holes of Water—3*, dated October 3, 1966. Note Schneider's query, "What happened to the multiplexer?" at the lower left, suggesting the ad hoc and evolving nature of the performances even at this late date. Image courtesy the Robert Rauschenberg Foundation © Robert Rauschenberg Foundation (no. 66.CD012).

provided a visual representation of what each artist envisioned while committing them to a plan of action that the engineers could execute. Schneider's drawings also became, after a fashion, art in their own right when Pontus Hultén superimposed all ten of them for the cover of the *9 Evenings* program.

The aggregate complexity of the TEEM system revealed some inconvenient realities. For example, miles of wires and cables linked to scores of devices resulted literally in thousands of jacks and plugs. Moreover, adding a new piece of equipment meant two or more additional points of connection were then needed. Faced with this "bane of numbers," the engineers realized with growing dismay that, with two or three performances planned for each night, rapid changes of equipment would be necessary.[83] Engineer Schneider observed that *9 Evenings* would not be some "one-night stand" at a Long Island summer theater.[84] Just as the phone company had once used switchboards to physically connect calls, the engineers decided to build a similar system they could monitor and operate from Central. The engineers compared it to an old-style "telephone switching office, allowing various subscribers to be interconnected."[85]

Feeling a growing sense of panic as opening night loomed, the engineers needed a way to address the problem of quickly swapping out equipment for each performance. "The idea," Schneider wrote soon after *9 Evenings*, "was simple: to make as much of the TEEM gear available as possible on patch boards." The idea of patch boards was familiar to engineers who remembered when telephone calls were manually connected by completing circuits using cords and plugs. "Related to switchboards as ancestors, the patch board allowed," Schneider explained, "each piece to be preprogrammed."[86] Different patch boards for each artist's piece could, in other words, be prepared in advance. Like a switchboard, all the nonportable audio and lighting equipment would be permanently wired into the patch boards. And then, for each artist's performance, the proper "program" would be inserted into a master control panel, making the appropriate electrical connections. At least that was the idea.

While logical in principle, the patch board system proved enormously troublesome in practice. Locating the necessary hardware was only the beginning. Eventually, engineers convinced Automotive Marine Products, a small company in Harrisburg, Pennsylvania, to loan them equipment. Then came what Schneider called the "saga of the tiny plugs"—thousands of feet of wire and coaxial cables with the proper connectors attached to their ends had to be made by hand. With only a few days to go before *9 Evenings* started, the artists, along with dozens of friends they had recruited, learned firsthand how to wire patch boards and strip cable ends. At one point, Simone Forti went looking for John Cage and found the famous avant-garde composer off by himself, patiently crimping wires.[87]

Despite such efforts, the patch boards with their spaghetti-like tangles of wires were still being hurriedly assembled on opening night. The results were predictable. Mismatched connections, loose wires, and untested equipment plagued the first performances. "I didn't have the presence of mind to put a stop to what I saw was happening," Klüver told Forti soon after *9 Evenings* ended, "and start the engineers working on a simpler system. What they had set out to do was a three month job." Weeks later, when the engineers clinically assessed what worked and what didn't, they estimated the hastily built patch board system caused "90% of all difficulties."[88]

While the engineers and artists labored furiously to get ready for the October 13 opening, Klüver and Rauschenberg were busy promoting *9 Evenings: Theatre and Engineering*. In August, Klüver had arranged, with help from Seymour Schweber, for a high-profile public relations firm named Ruder and Finn to advertise the event. Rauschenberg, meanwhile, designed a colorful poster for the show and offered some of his artworks as collateral to offset *9 Evenings*' rapidly rising costs. In late August, Ruder and Finn began touting the "extraordinary cooperation between artists and scientists"—the engineers still struggled for proper professional recognition—and reached out to venues like the *Ed Sullivan Show*.[89]

Ruder and Finn's press releases highlighted how *9 Evenings* relied on a platoon of experts working in their spare time—Klüver made sure this point was emphasized—to "find solutions to performance problems" posed by artists' new concepts. Technology "opened the door to a new freedom of expression" and suggested the "possibility of virtually limitless new media" for future art experiments. Everyone would benefit. Audiences would be culturally enriched and better informed about modern technology. Engineers would get the benefit of "stimulating and improbable challenges" different from the routine problems they encountered in the workplace. And, the "formal lasting alliance" between artists and technologists suggested that corporate patrons could enjoy the "commercial potential of scientific discoveries."[90]

The promotional campaign culminated in a press briefing held in late September, just a few weeks before *9 Evenings* opened. Reporters from diverse publications—*Vogue*, the *Saturday Evening Post*, and *Electronics News* were all represented—convened at Rauschenberg's studio loft. As he welcomed the guests, Klüver expressed his views about the relations between art and technology. Relative to the support society gave to engineers and scientists, artists were "undernourished," and yet everyone still had an opinion about what artists did. Likewise, too many people were uninformed about the research done at places like Bell Labs. Klüver encouraged people to see the performances as experimental investigations rather than viewing them simply as art. From a professional engineer's perspective, Klüver confessed that all of the art-and-technology projects he had worked on were alike in one key way: "They are ridiculous." But stimulating "new ways of looking at technology and of dealing with life" was their value. Engineers' encounters with the "unique intuition and insight of the artist" was "the greatest gift art can make to research."[91]

While Klüver extolled the virtues of artist-engineer collaborations, Rauschenberg, personable as always, chatted with journalists and art critics. "Working with engineers is inspiring," he told one writer, "I could not do what I wanted to do without them. It is no longer possible to bypass the whole area of technology." He recalled how his teenage son, Christopher, preferred math and science over art. But, Rauschenberg speculated, if his son became an artist (which he eventually did), then knowing physics or engineering might be necessary. "There are uncharted worlds yet to be discovered, technological worlds that could totally change the face of theatre," engineer Robby Robinson added. Rauschenberg agreed, "I can foresee art schools giving courses in electronics and vacuum molding. We can't afford to wait."[92]

Ruder and Finn proved quite successful in promoting *9 Evenings*. In the week leading up to opening night, for instance, Klüver appeared on at least three different television or radio shows to stress the social value produced when "artists and engineers can talk to each other." Nonetheless, Ruder and Finn's own approach to filling seats—at $3 a ticket—tended toward sensationalism. The company's advertisements implied that audience members would witness miraculous spectacles more akin to a carnival than avant-garde art performances designed as experiments in collaboration. "You will see without light. . . . You will see dancers float on air. . . . You too can actually float," a poster read, concluding, "It's important that you attend."[93] While not technically untrue, the strategy certainly created some unreasonable expectations. The pump was primed even more when, just before *9 Evenings* started, the *New York Times* ran a lengthy profile of Rauschenberg. Describing the artist as both a "playwright and engineer," Rauschenberg was photographed with one of the special tennis rackets that engineers had made for *Open Score*.[94]

Meanwhile, back at the Armory, artists and engineers continued to cut, crimp, solder, and splice right up to and then past the advertised starting time on opening night. Hundreds of curious people milled around olive-drab army trucks displaced from their usual parking spots inside the Armory while taxis brought ticket holders and hopefuls to its massive front door. The first performances of *9 Evenings* (Alex Hay's *Grass Field*, Deborah Hay's *Solo*, and Steve Paxton's interactive environment *Physical Things*) fell on a Thursday. Even larger crowds materialized the next night for David Tudor's *Bandoneon!* and Rauschenberg's much anticipated piece.

When the doors finally opened, the crowds slowly shuffled inside to discover that engineers and artists had transformed the Armory into "a world of wires."[95] The gaggle of art critics and reporters couldn't help but notice the celebrities in attendance, such as fashion designer Joan "Tiger" Morse (clad in what one reporter described as

Figure 4.6 Artist and choreographer Deborah Hay working with engineer Cecil Coker, October 1966. Image courtesy the Klüver/Martin Archives (photographer unknown, all rights reserved).

a “bare midriff costume of white vinyl” and carrying a portable lamp that enveloped her “in a violet glow”) circulating throughout the crowd. Susan Sontag chatted up Allen Ginsberg while Andy Warhol, wearing a leather jacket and sunglasses, languidly pronounced the whole event as “great, just great.”[96]

As the Armory filled to capacity, the engineers found themselves in an increasingly distressed state. Robby Robinson fretted to Simone Forti, “You guys are emotionally prepared for this. We aren’t.”[97] Artists, journalists, socialites, Wall Street executives, and denim-clad university students took their seats and waited to see what would happen. The experiment had been switched on.

5

TRANSDUCER

> Industry and business must also help the artist gain greater familiarity with the new materials, methods, and instruments science has to put at his command.[1]
>
> Frank Stanton, 1967

Clive Barnes had been an art critic at the *New York Times* for little more than a year but he had already displayed a distinct antipathy toward the kind of experimental art that *9 Evenings* presented. In one review, the Oxford-educated Barnes referred to an avant-garde performance at the Judson Church as a "village disaster" created by "eager children of the dance explosion . . . with their feeble little pomposities" and "silly, tiny tape-machines."[2] His reaction to *9 Evenings* was equally caustic.

After attending—or, as he saw it, enduring—two nights of performances at the Armory, Barnes was appalled. He seemed unable to decide which to blame more—the artists' work ("vilely done . . . amateurism"), the docile audience ("lemmings headed for a precipice . . . flame-hungry moths urged on happily to their final immolation"), or the technical glitches ("apparently unsound sound equipment"). The whole thing was an exercise in conformity and audience manipulation, he said, presenting experiments "not in art or even technology, but in sociology," and this was of a perverse sort. Barnes extended his inventory of rebukes to indict the engineering community. "If the American engineers and technologists were typical of their profession," he fumed, "the Russians are sure to be first on the moon."[3]

The artists of *9 Evenings* were used to negative reviews. But for the engineers, the public castigation, not just of their shortcomings but of their entire profession, was a new and extremely unpleasant experience. Their visceral reaction to Barnes's summation—"God bless American art, but God help American science," the critic said—was immediate and sharp. "My ethics, ability, and knowledge were as fine as my motives," engineer Robby Robinson wrote, "I wasn't about to surrender to his gutless play of words."[4]

Klüver, who typically maintained a public sense of detachment, was especially incensed. For transgressing into allegedly foreign territory—Klüver recalled Barnes telling him that bringing artists and engineers together was morally "wrong"—the engineers were punished by ignorant critics who proudly understood "absolutely nothing about technology." Klüver had a point here as Barnes and other critics typically failed to note the many times the technology did work as planned. David Tudor, for example, experimented with an ensemble of programmed sound, mobile loudspeakers, variable lighting, and visual images, along with the Armory's own acoustics, to create his *Bandoneon!* piece. Unwilling to get basic technical facts right, Barnes had unjustly dismissed Klüver's accomplished colleagues as "incompetent amateurs." (Barnes admitted, however, that he didn't stay long enough to hear the first performance of Tudor's piece.) Privately, Klüver fumed that Barnes had "done us more harm and caused me more sleepless nights than the whole goddamn *9 Evenings*."[5]

Critics' harsh reaction to *9 Evenings* might have been amplified further by their overexposure to major modern art events. Just a month before the Armory show, for example, Central Park hosted the fourth Annual New York Avant Garde Festival, organized by cellist Charlotte Moorman. But Barnes and his colleagues certainly couldn't be accused of ignoring *9 Evenings*. The *Times* alone published a half dozen articles about the event while writers at other regional and national venues contributed many more pieces. And while Barnes's reaction typified the response of many art critics, not *all* the reviews were bad. Although better attempts to explain the technology might have benefitted audience members, an electronics magazine proclaimed "the engineering was beautiful and the performers functional." The *Wall Street Journal*, meanwhile, told its business-oriented readers of the potentially profitable "'feedback' to industry" that future collaborative experiments between engineers and artists—"tentative and quite rough around the edges" though they might still be—could yield.[6]

Jill Johnston, an experienced dance critic for the *Village Voice*, reminded her readers that before critics enshrined the 1913 Armory show in art history, it too was initially judged an aesthetic fiasco. *9 Evenings* might again prove that "disasters have beautiful side effects." Johnston also took a sympathetic view of the larger goals Klüver and his colleagues had. "There is no question in my mind," she wrote, "that the whole idea of Theatre and Engineering is a concept of world-shaking dimensions . . . the idea will live on."[7] Engineer Herb Schneider agreed. He believed the biggest accomplishment was "bridging a supposed gap" between two different creative communities and laying the foundation for a new hybrid culture. "It's been fun," he wrote Klüver, "and must continue."[8] This chapter explores just how this growing community of artists and engineers kept their experiment going.

THE UNDEVELOPED COUNTRY

The mechanism Klüver and his collaborators constructed to continue their "social-technical-aesthetic" research was Experiments in Art and Technology. The choice of the organization's name was subject to considerable debate in 1966. Something mundane like Foundation for Artists and Engineers was considered but the group's lawyer noted that having the word "engineering" in the organization's name could raise liability questions. "Experiments" provoked criticism as well. "An artwork is finished or it isn't," Klüver recalled, but others thought it could poke at "bourgeois values" about the nature of art itself and so it was kept.[9]

E.A.T. was established as a nonprofit group in New York State—Klüver, Rauschenberg, artist Robert Whitman, and engineer Fred Waldhauer were its official cofounders—in late September 1966, but the media glare surrounding *9 Evenings* obscured the news. (Which probably explains why many scholars place its creation *after* the *9 Evenings* performances.) Officially, E.A.T.'s incorporation papers stated that it would offer assistance to "further the development and the interaction of art and engineering." Keeping with his technical background, Klüver publicly proclaimed E.A.T. would serve as a "transducer between the artist and the industrial laboratory."[10] For an electrical engineer, this was a sensible comparison. Transducers, such as microphones, convert one form of energy into another. E.A.T.'s mission was to transform engineers' technical knowledge and corporate resources into both new artworks and a new, more transparent perspective on technology for the public. In exchange, engineers would have new possibilities and partners for their creativity, which in turn might be converted into new research and inventions.

Max Mathews, an electrical engineer at Bell Labs and pioneer in computer-generated music, offered a different but perhaps more telling analogy. He suggested that making technology available to artists was like "supporting an undeveloped country." Just as they were assisting once-colonized people in places like India, Latin America, and South Vietnam, engineers could give artists "vital ingredients" including education and equipment. But, nearly a decade after C. P. Snow's broadside, the language of estrangement still resonated. Because modern technology was changing so rapidly, Mathews proclaimed that time was of the essence in order to prevent "art and technology from becoming hopelessly separated."[11]

As it tried to get off the ground, E.A.T. faced several tasks. The first of these was assessing the aftermath of *9 Evenings*. By Klüver's accounting, some thirty engineers had volunteered about 8,500 hours for an event that cost upward of $160,000. To get a clearer sense of what worked and what hadn't, he sent a detailed questionnaire to the participating artists and engineers. While the artists returned mostly perfunctory, sometimes monosyllabic responses, the engineers provided exceptionally candid and verbose evaluations. They ranked equipment in terms of failure rates and wrote detailed reports about each artists' piece just as a researcher might evaluate a lab experiment. While all the respondents wished more time had been available for rehearsals and (especially) equipment testing, artists and engineers alike said they wanted to collaborate again in the future.

Walter Gutman, who had contributed funding and guidance, also offered his frank assessment. While he judged *9 Evenings* itself as "not a particularly interesting achievement"—the artists had distinguished themselves better, he thought, in other works—"certainly no one can criticize an experimental effort, if it is accepted as experimental." Gutman encouraged Klüver to remain objective in assessing outcomes even though it was "easier to maintain an attitude of constructive evaluation with respect to molecules or electrons than it is to human beings." Instead of viewing artists as a community that "needs help," perhaps it was, he suggested, the engineers who would ultimately be the "main beneficiaries of E.A.T."[12] Klüver agreed, although it might be "ten or twenty years before the significance or insignificance" from *9 Evenings* was clear.[13]

Evaluating past accomplishments was one task. But recruiting artists and engineers to the cause and organizing them for future action was more critical. At the end of November, refreshed after a long vacation in Europe, Klüver met with artists and engineers from *9 Evenings* at a Greenwich Village hotel to discuss E.A.T.'s future. About 300 people, responding to what was billed as "the 10th evening," joined them. Their immediate goal was seeing how engineers and artists could work in an "organic, collaborative way."[14] Asked to provide an opening commentary, critic

Brian O'Doherty, who had written sympathetically about *9 Evenings*, noted that, while art and technology might appear as "magic words," few people gathered that evening held "any illusions about the mystiques of technology or that science is an idealistic system." Instead of artists continuing to hunt randomly like some "isolated animal" for solutions to creative problems, E.A.T.'s technical experts could facilitate the process.[15]

Fred Waldhauer emphasized the "positive feelings" that *9 Evenings* generated for both groups of collaborators. He had helped set up E.A.T. because some "engineers feel art is important to society," and yet it remained underfunded and underappreciated. Meanwhile, artists who participated in *9 Evenings* believed that maintaining their contemporary relevance demanded more "sensitivity of technological media." When it came to practical matters, engineer Herb Schneider stated E.A.T. should "foster a discourse" between "artistic and technical people."[16] And "even though none of us want to be called an 'Organization Man,'" he said, some type of management would be needed to bring two diverse communities of creative people together. Rauschenberg agreed, insisting that E.A.T., even as it grew organically, would need to articulate both a structure and a mission or else it would become yet another "ineffectual" foundation.

Klüver noted that artists would need access to what he called "E.A.T.'s capital" (i.e., the equipment built for *9 Evenings*). According to the meeting's transcript, they were especially interested in accessing tools like computers, semiconductors, and lasers as well as even newer technology that was still in "the lab stage." But because this technical "capital" was limited—and, after *9 Evenings*, in need of repair—some procedure was needed for deciding which artists could access it. This, in turn, raised tricky questions of talent and quality. "Who will decide on artists' projects?," audience members asked. "Which artist decides which artist passes? Would engineers also be producing art?" Just as sensitive was the question of censorship and political views. Could someone "do a piece against USA, industry, racism?" or would E.A.T. act to quash artists' political messages? Aside from finding "an engineer who feels the same way," Klüver proposed no such censorship. "Whatever you want to do," he said, "you should try to push it to the limit," even if it might be politically controversial.

Carolee Schneemann was one of the first artists to avail herself of the engineering assistance E.A.T. offered. Like Rauschenberg, she had started her career as a painter but then moved into performance art in the early 1960s, partly through association with the Judson Dance Theatre. Her 1964 piece *Meat Joy*, featuring eight near-naked performers writhing about in paint and raw meat to the beat of a pop music soundtrack, helped establish Schneemann as a leading feminist figure in the male-dominated avant-garde art scene. Her vision for a new intermedia piece called *Snows*—her reaction to the violence of the Vietnam War—would immediately test E.A.T.'s hands-off policy regarding political statements. "The war," she recalled, was like "a force of nature that never ceased enveloping . . . fierce inescapable weather," and she titled her work likewise.[17] *Snows*' unambiguous message of protest also stands as a counterpoint to later critics of art and technology who claimed the community rejected engagement with political and social issues.

As she planned *Snows*, Schneemann recalled driving out to Bell Labs—E.A.T. had not yet moved its operations to Manhattan—where she found herself "picking and choosing like crazy in Woolworths: the transistors, these cables . . . the stuff all looks very junky, mute, and utterly unrelated to the images it will go to realize . . . it's all mysterious promise." Back in New York, Schneemann, working with engineers Per Biorn and Robby Robinson, started designing a complex electronic environment. "The technical possibilities of the equipment we had was generating ideas which could take months to realize," she recalled. Ralph Flynn, a young engineer at Bell Labs who worked on sound amplification technology, also joined the effort. Flynn, for instance, rigged the theater's seats with contact microphones that would "pick up random noises from the audience movement."[18] (The engineer eventually left his Bell Labs job and joined E.A.T. where he met and married one of the group's administrative assistants.)

People who saw *Snows*—it opened in late January 1967 as part of the Angry Arts Week—witnessed an interactive light and sound environment Flynn and the other engineers had built. On stage there were colored lights, suspended bags of colored water, and hanging ropes tied like nooses. Films combining images of wintry scenes with war atrocities were projected onto the set while performers acted out roles of victims and persecutors. All the while, artificial snow fell about them. To contrast with the unsettling visual imagery, Schneemann added an upbeat soundtrack of classical and pop music (augmented by the sounds of her having sex with her husband, James Tenney, an experimental composer, cross-mixed with train noises). As planned, audience members shifting in their seats contributed random acoustic signals that triggered unexpected lighting and sound changes.[19] After *Snows*' run of eight performances ended, Schneemann mused on the artists' use of technology. "My problems with technology are concrete, personal," she wrote, "the work of technicians should become one other action parameter of my work. . . . this means greater familiarity with possibilities of available technology and time to explore: a diet of E.A.T."[20]

Schneemann's *Snows* was just one of several art-and-technology projects that helped raise awareness about E.A.T. among engineers and artists. Like many grassroots organizations, the copy machine proved a valuable if underrecognized tool as mimeographed posters and newsletters spread the word. E.A.T.'s first newsletter laid out the organization's role as a "transducer" situated between artists and the industrial lab. Rather than "wasted time and misunderstandings," E.A.T. would translate artists' problems "into a suitable technical language" and familiarize their community with "technology, the engineer's personality, and language." While the goal was "for the artist to realize his work and to provide creative stimulation for engineers," when it came to potential intellectual property, E.A.T. proposed that "all patents and commercial ideas" belong to the industrial laboratory that provided technical expertise. Although its initial center of gravity was the New York art scene, Rauschenberg and Klüver spoke of E.A.T. as an eventual "nationwide project" that would provoke "science, money, industry and art to work together to make work that could not exist otherwise."[21] Finally, as he looked further into the future, Klüver imagined E.A.T. as a transient organization that was necessary for the moment. But, as it became successful, he expected that "many of its functions" would eventually be "transferred to industry, to the professional engineering societies, and to universities."[22] As art and technology became less experimental and more everyday, society's need for E.A.T. itself would fade.

The "marvelous thing" about E.A.T., as Klüver told businesspeople he spoke with, was that "it acts in both directions." Besides the possibility of patents, artists' "non-formal pattern of thinking" offered engineers an "economic way of stimulating ideas." Meanwhile, industry's support for artist-engineer collaborations could win them "prestige or advertising" benefits just as companies had already profited by advertising their connections to "satellite or rocket research." A cartoon Klüver scribbled captured this belief in mutual benefits: a blocky-looking stick person with E.A.T. as its torso and "Artists" and "Engineers" as the feet holding it upright. And, in the collaborative creature's hands, were an American flag and a flower.[23] We don't know, however, if, by marking the figure's head as "Industry," Klüver was signaling that the ideas would flow from that portion of the partnership.

Keeping in line with opinions he formulated as a student at Berkeley, Klüver was eager to see E.A.T. influence how people understood technology. "We are in dire need of more fantasy, more imagination," Klüver wrote to E.A.T. supporters, "and perhaps more madness in the use of technology."[24] That Klüver sometimes referred to himself as a "work of art" was not meant as an egotistical proclamation but rather signaled "the rise of technology to a new place of equality in art."[25] Klüver and other E.A.T. members consistently stressed that their organization was not concerned with *what* artists produced but rather *how* it was produced. As Klüver told one journalist, "We're not interested in art." So, why then did "art" appear in his group's name, the confused reporter asked. "That's a lawyer's idea," Klüver replied.[26] By favoring collaborative processes over artistic products, E.A.T. was embarking on a sociological and political project as much as a cultural one.

Any project this ambitious was going to be neither inexpensive nor easy (and E.A.T. already had a substantial deficit from *9 Evenings*). Klüver initially estimated that operating E.A.T. would require an annual budget of $85,000, a projection that, by January 1968, had increased to $200,000. (To put this in perspective, the entire budget of the National Endowment for the Arts was around $8 million.) While they prepared proposals targeting established philanthropic foundations, Rauschenberg's and Klüver's connections allowed them to cobble together about $30,000 to help carry it through its first year.[27] Continued media coverage raised the group's profile among potential patrons. Grace Glueck, an arts writer for the *New York Times*, noted that while *9 Evenings* may have "flickered feebly," a larger art-and-technology movement was gathering momentum nationwide. "It's like we've been holding a monster by the tail," Klüver told her, "we don't want it to get stuck in the door."[28]

An essential tool to move the monster was a large group of engineers interested in working with artists. Ultimately, E.A.T. wanted 1,000 engineers or more, drawn "from all parts of industry," to fill its ranks. Klüver emphasized that it was important for individual engineers to contribute but, even more so, their industrial employers should meet their "social obligation" and "take on the artist's problems" by contributing people and money. Klüver's colleagues at Bell Labs, including John Pierce, his supervisor, gave verbal support to the core ideas behind E.A.T. while articles in engineering magazines helped bring art-and-technology efforts to the attention of Klüver's fellow engineers.[29] To help generate greater participation, E.A.T. approached the Institute for Electrical and Electronics Engineers (IEEE), a professional organization for electrical engineers, about forming an official "Engineering in Art" group. To make his case, Klüver deployed the still-useful phrasing of C. P. Snow, and challenged IEEE to help "bring the two cultures together." Despite all of these efforts, enlisting engineers remained a challenge. By mid-1968, E.A.T. reported that only about 450 engineers (compared to about 1,000 artists) had contacted the group.[30]

Figure 5.1 Tom Gormley (center) and Hans Haacke (right) recruiting for E.A.T. at an IEEE meeting, E.A.T. staff member Gene Ehrlichman is in background. Image courtesy the Klüver/Martin Archives (photographer unknown, all rights reserved).

Nevertheless, engineers' interest in partnering with artists continued to slowly spread beyond New York City. As one researcher at MIT who joined E.A.T. said, "The engineer and the artist have many things in common; most importantly the creative urge."[31] But what was it that compelled engineers to volunteer time at the art-technology nexus? As Klüver told one arts foundation executive, curious technologists were interested in "cultural aspirations, artistic aspirations" and were "often motivated by different interests than the run-of-the-mill engineer who does not care about art."[32]

Engineers joined E.A.T. for all sorts of reasons. One person who eagerly responded to the opportunity to work with artists was John Forkner. Born in 1927 in Philadelphia, Forkner pursued interests in amateur astronomy and rocketry before earning degrees in physics at what was then called the Drexel Institute of Technology. He then moved to Southern California for a job in Newport Beach as an optics specialist for Philco Aeronutronic, a division of the Philco-Ford Corporation. Among the projects Forkner's company worked on were infrared-detecting missile systems and NASA's mission control systems at Johnson Space Center. Unmarried and with a distinctive, long red beard, Forkner wasn't the conventional Organization Man who worked from nine to five before returning home to his suburban family. Interested in modern art, jazz, and making pottery, Forkner found that the art-and-technology movement provided him with a new path to express his personal creativity. In his spare time, for example, he experimented with "optical projection devices as a possible artistic medium."[33] "The emotional element in industry is a thing to be eliminated," he told an art writer in 1970, "but in the collaboration of art and technology, that's the whole justification. Emotion is where the energy comes from."[34] In his application to E.A.T., Forkner wrote "Your idea sounds great! I've believed in this for many years." Forkner was soon collaborating extensively with E.A.T.'s cofounder Robert Whitman and became a key figure in West Coast art-and-technology initiatives. For Forkner, who we will meet again later, collaborations with artists changed his whole professional trajectory.

Although Klüver believed that industry and corporate labs were the best places to recruit engineers and find financial support, he didn't neglect universities. In April 1967, he gave a talk to engineering students and faculty at MIT that spelled out why he was invested so much in the shift to art and technology. One of Klüver's clearest articulations of E.A.T.'s mission, he presented the talk, titled "Interface: Artist/Engineer," as an intermedia performance of sorts. As a prelude, carousel projectors flashed through four waves of slides accompanied by Klüver's tape-recorded voice. He then used six viewgraph machines, switched on simultaneously, in conjunction with a whole series of overhead slides with text and images.[35]

"There are two things on people's minds when they think about the future," Klüver stated in his opening, "drugs and technology." (This was 1967, after all. Just a few weeks earlier, Timothy Leary had exhorted people to "tune in, turn on, and drop out.") On the other hand, Klüver said, technology encouraged people to interact with society and also try to change it. "Few artists I know take drugs but all are interested in technology," he stated, "and wish to be involved with society." Aware of his audience's background, Klüver likened what was happening in the art world to the revolution in quantum physics. Physicists in the 1930s and artists in the 1960s were both "committed to a vision solidly anchored in reality" that could *do* useful things rather than dwelling on unnecessary metaphysics. What if, Klüver asked, some artist in the 1950s had asked for a thin beam of light? Might not this have resulted in the laser being developed sooner, perhaps shaping its development in unpredictable and exciting ways? Or, if artists had been consulted when computers were being designed, maybe graphical output and imagery from them would have appeared sooner.

Looking beyond E.A.T., Klüver argued that the emerging art-and-technology movement should be of concern to science educators. “Reading articles about the two cultures on Sunday afternoon and educating engineers in the liberal arts,” he said, “should not give us the same comfort anymore.” Engineering programs needed to “promote understanding of the artist’s condition and the way he works.” More broadly, technologies (and technical institutions) needed a makeover so that the public saw them as “more human, more reasonable . . . more lifelike.” Good intentions aside, building bridges across cultural divides called for more than just dedicated individuals. “We need engineers,” Klüver said, but “if industry does not get involved, the artist/engineer collaboration will go down with a whimper.”

Klüver emphasized that E.A.T. did not want to turn engineers into artists nor did it want to adjudicate what was *good* art. Referring to Marcel Duchamp’s *In Advance of the Broken Arm*—the artist’s famous display of a snow shovel—he noted that it took more than talent and materials to make an artist. “We resist all aesthetic choices like the plague,” he said, “the motto of E.A.T. is ‘Technology does not make new Art.’” And, just as it welcomed all serious engineers, E.A.T. was open to all artists. After all, Klüver said, using a reference he knew would amuse his audience, “the American Physical Society admits all papers to their conferences. We never hear about bad scientists the way we do about bad artists.” Artists, talented or otherwise, could benefit engineers and other researchers simply by the questions they asked and the aesthetic demands they made. “Technology needs the artist just as much,” he said, “as the artist wants technology.”

ASSEMBLING ALLIANCES

Throughout the 1960s, books questioning the power and proper place of technology in Western society, written by intellectuals like Jane Jacobs, Herbert Marcuse, and Lewis Mumford, filled store shelves and students’ satchels.[36] Typically, such assessments treated the topic rather vaguely, speaking of an abstract “Technology with a Capital T.” That is to say, before academics added nuances like “social constructivism” and “technological determinism” to the mix, public intellectuals often reduced technology to an all-encompassing force that autonomously shaped modern society.

Billy Klüver likewise veered toward such abstraction in his own writings about technology and society. But, as E.A.T. gathered momentum, an opportunity arose for it to engage directly with a pressing and quite specific issue that concerned technology.

Throughout the 1960s, workplace automation stood as one of the central issues at the intersection of technology and modern society, as journalists and other writers churned out thousands of newspaper articles and books. They had plenty to write about. In 1962, the New York Transit Authority unveiled subway trains that needed no human operators while astronaut John Glenn argued that rocket engineers should "get rid of some of that automatic equipment and let man take over."[37] As a presidential candidate, John F. Kennedy juxtaposed automation as a "new hope for prosperity" while warning of its "dark menace."[38] Workers and policy makers alike agreed with Kennedy that labor displacement via technological change presented "the major domestic challenge" of the 1960s. This concern was reflected across the political spectrum. In 1964, leaders of Students for a Democratic Society cosigned "The Triple Revolution," a manifesto warning about the loss of jobs and workers' dignity due to "automated, self-regulated" machines. A year later, leaders of the nascent neoconservative movement devoted the first issue of *The Public Interest* to "the great automation question."[39]

Theodore W. Kheel closely monitored the increasingly rancorous debates about automation. As one of the era's most prominent labor mediators, he had long been concerned about the effects of new technologies on American workers. In 1962, unionized printers alarmed about the encroachment of automated typesetting systems walked off their jobs, shutting down New York City's newspapers for almost six months. Kheel's role in brokering a settlement between publishers and labor leaders brought him national attention. Some observers expected him to run for public office. Kheel used the attention to help start the American Foundation on Automation and Unemployment, which aimed to help resolve worker-management conflicts catalyzed by new technologies, eventually becoming its president.

In the summer of 1967, Kheel took a lunch meeting with Klüver and Rauschenberg. He quickly realized, as he later recounted to Calvin Tomkins, that "there was an identity of interest."[40] "What attracted me to E.A.T.," Kheel recalled, "was the concept, not the art." After the meeting, Klüver helped arrange a personal tour of Bell Labs for Kheel so the labor mediator could see firsthand what new technologies might affect automation and labor.[41] Both Kheel and Klüver were "interested in using technology to help the individual" and both had seen firsthand, although in very different ways, the “frustration” that could arise if people couldn’t use it how they wanted. Kheel, obviously, was invested in worker-management issues. Klüver, likewise, explicitly envisioned E.A.T. positioned as a “mediator” that would foster “effective working relationships” between artists, engineers, and industry.[42] Both men, in other words, sought to promote mutual interests between different groups that ordinarily might stand in opposition to one another.

When Kheel first met Klüver and Rauschenberg (or, as he knew them, “Billy and Bob”) he observed that “anybody who gave two cents for the future of E.A.T. probably stood a good chance of losing his two cents.” Nevertheless, Kheel contributed far more than that—eventually, over $10,000 of his own money—to support E.A.T.’s mission. He also told them about an upcoming opportunity. Earlier that year, Margaret Rockefeller Strong, the favored granddaughter of John D. Rockefeller Sr., had sold a mansion to Kheel’s Foundation on Automation.[43] The six-story building on the Upper East Side, listed as a historic landmark, would serve as the organization’s new headquarters. Kheel imagined hosting activities like labor-management seminars and occupational training programs. But Kheel also envisioned “Automation House” as a “multi-purpose place” that would “demonstrate the capability of new technology to help the individual.” To support this goal, he offered E.A.T. some space in Automation House for the group’s headquarters. While helping promote “interest in art forms developing from new technology,” Klüver and his colleagues could also interact with leaders from the labor movement and national unions.[44]

Artists like Rauschenberg also pondered the effects of automation and other new technologies on their profession and the commercial value of what they made. Photography and modern lithography, had, of course, allowed artists to easily reproduce images at low cost. In the early twentieth century, the surrealists had explored means of letting the unconscious mind to “automatically” take control over movements of the artist’s hand. Later on, abstract expressionists like Jackson Pollock embraced a kind of “romantic automatism” while composer John Cage’s infamous “prepared piano” pieces represented another form of automating the creative process.[45] But it was in the early 1960s that a new technology—the digital computer—threatened to upend the very nature of who made art and what it actually was.

Klüver’s employer was actually one of the sparkplugs for this transformation. As at many labs, researchers at Bell Labs connected peripheral devices to digital computers to visually display data. Early on, the results might be presented on a cathode ray tube and photographed with a high-speed camera, resulting in short animated films, or plotted out on rolls of paper. For example, A. Michael Noll was studying new methods for determining the pitch of human speech. To visually display the information his research generated, he relied on a microfilm plotter linked to an IBM mainframe computer with a Fortran program controlling the interface. However, during one computer run in 1962, a programming error caused the plotter to serendipitously produce a visual mess that one technician jokingly referred to as "computer art." Intrigued, Noll, an admirer of abstract art, deliberately altered the program so it generated compositions he designed. Like Frank Malina, Noll gave these images scientific-sounding titles, such as *Gaussian-Quadratic*—it used, in part, a random distribution of end points to generate horizontal line segments—and *Ninety Parallel Sinusoids*, which was an interpretation of Bridget Riley's op art pieces. In keeping with Bell Labs' tradition, Noll described these experiments in technical memos that he sent to upper management. Keen not to provoke discussions as to what was "truly art," he designated the "results of the machine's endeavors" simply as "patterns."[46]

Noll was not the only person at Bell Labs experimenting with computer-generated imagery that some might see as art. In 1966, two other researchers, Kenneth C. Knowlton and Leon D. Harmon, developed a technique to convert an existing image, such as a photograph, into a series of numerical "gray-scale" values. By assigning small, pixelated symbols to each value, they could convert the original image into a mosaic. An early example of this technique was an image they made in 1967 called *Nude* or *Studies in Perception I*. After transforming a photo into some 16,000 picture points, they printed it out as a five-foot-by-twelve-foot image. When looked at up close, it dissolves into incoherent patterns but, from a distance, a reclining nude woman—their model was *9 Evenings* performer Deborah Hay—comes into view.

These early uses of computers to produce artworks eventually caught the attention of gallery owners and art critics. Howard Wise, who operated a New York gallery that specialized in multimedia, light, and kinetic art, saw an image by another Bell Labs scientist, Béla Julesz, on a cover of *Scientific American*. Julesz, a Hungarian-born experimental psychologist, was using randomly generated patterns of dots to study stereoscopic depth perception. Wise invited both Julesz and Noll to display their work for a small show he organized called "Computer Generated Pictures." While it was the first exhibition of art by algorithm in the United States, similar shows had already taken place in Europe.[47] Despite the seeming novelty, as Noll recalled, AT&T's management didn't want it publicly known that Bell scientists were making art so he and Julesz copyrighted their pieces under their own names.[48] When the *Times* reviewed the show, its critic described the artworks as “bleak, very complex, geometrical patterns.” More promising—the real “wave of the future”—was that art had been made using computers and the people doing it were engineers and not professional artists. “Scientists predict a time,” the article revealed, “when almost any kind of painting can be computer-generated.” Just as workers’ physical labor and skills were no longer as essential for making cars or setting typeface, it was possible to imagine a future when “the actual touch of an artist will no longer play any part” in making art.[49] Although art writers would frequently declare early computer-generated artworks as “ugly and frequently pointless” creations, the idea that machines might substitute for artistic originality had parallels to the concerns about automation among American labor leaders and workers.[50]

E.A.T.’s new connection to Kheel and Automation House coincided with a major push by Klüver and Rauschenberg to “establish high level contacts with industry.”[51] Well-positioned people like Marian Javits, an arts patron married to Senator Jacob Javits, and John G. Powers, a collector of pop art and president of what today is the Aspen Institute, offered connections to executives at blue-chip companies like Xerox and Atlantic Richfield.

E.A.T.’s appeal to International Business Machines typifies the circuitous path that fundraising required. Even though Klüver himself was neutral about the value of computer-generated art, having modern computers available for artist-engineer collaborations was an obvious goal. Initially, Klüver intended to approach Thomas Watson Jr., IBM’s president, directly. Marian Javits knew Watson personally as IBM was headquartered in New York, the state her husband represented in the Senate. Klüver’s sources, however, told him that Watson was “not interested in art” and that he regarded artists’ use of computers as a “waste of time.” What *did* interest Watson was employee turnover at his company. He worried that well-trained engineers, having become bored with their jobs, might leave “Big Blue” for other career opportunities. As one executive told Klüver, E.A.T. could offer IBM the equivalent of a “better golf course” that would help retain technical talent.[52] In the end, Klüver and Fred Waldhauer pitched artist-engineer collaborations directly to IBM’s chief scientist, selling it as an opportunity to give engineers “new ways of looking at and doing things” and thereby keeping them engaged.[53]

By the end of 1967, Klüver had secured about $35,000 toward E.A.T.’s future operations. Most of this came via modest corporate donations from such companies as IBM and AT&T.[54] Reflecting the new partnership with Kheel’s Automation House, E.A.T. also received some contributions from national and local labor organizations.

And, as he had for *9 Evenings*, Klüver relied on assistance from wealthy individuals. Kheel, Powers, and Javits, along with early donors like Walter Gutman and Seymour Schweber, all gave generously. In recognition of their contributions, Klüver and Rauschenberg invited an ensemble of wealthy industrialists, gallery owners, museum executives, and prominent art collectors to serve on E.A.T.'s board of directors. Tucked away amid boxes of archival materials, for example, is a hand-printed appeal from Rauschenberg to Joseph C. Wilson, Xerox's president.[55] The note was effective as Wilson's company later contributed $5,000. In addition, a sympathetic cohort of "agents"—people like John Cage, John Pierce, and MoMA's Alfred Barr—agreed to "use their influence on behalf of E.A.T."[56]

As it raised funds, E.A.T. faced something of a paradox. While media attention helped generate donations, it also stirred up more requests from artists for technical assistance than the organization could easily meet. Additional engineers were needed but recruiting them remained a challenge.[57] Klüver came to believe that engineers who would work with artists only in their spare time were not a sufficient solution. He ideally wanted corporate managers to allow their employees to participate in E.A.T. as one facet of their service. This, he thought, offered companies an opportunity to make a "positive contribution in an increasingly alienated society" and possibly also get some good publicity. Anything more gradual would just be eroded by the "cynicism in the art world and the indifference of the technical community."[58] In Klüver's vision, the two cultures would be connected by a well-engineered, four-lane bridge, not some flimsy gangplank.

Successful collaborations also had to be safe ones. As artists experimented with new materials and tools, E.A.T.'s engineers could inform them about potential risks. E.A.T. eventually developed a safety program and worked with health officials to make sure that projects, like Robert Whitman's *Solid Red Line* (1967), where a red laser beam drew and then undrew itself on four walls, were properly done.[59]

While E.A.T was known to a small but growing cohort of artists and engineers, along with an even more select group of corporate executives and philanthropists, the wider world was largely unaware of its existence. This changed dramatically in October 1967 when some 300 invitees made their way to Rauschenberg's East Village studio for E.A.T.'s glitzy coming-out party. Amid Andy Warhol's floating *Silver Clouds* and Rauschenberg's sound sculpture *Oracle*, labor officials and politicians mingled with artists, engineers, and curators. The *New York Times* reported on the event with a story that also included—scandalously to some readers—Knowlton and Harmon's computer-generated nude portrait of Deborah Hay.[60]

WEDNESDAY, OCTOBER 11, 1967 The New York Times L+++ 49

Art and Science Proclaim Alliance in Avant-Garde Loft

By HENRY R. LIEBERMAN

In a sound-drenched Lower Manhattan loft building that was enlivened by revolving painted disks, film projections, floating pillows and miniskirted girls in paper smocks, representatives of industry and labor joined a number of artists and scientists yesterday to proclaim a "working alliance" between art and technology.

This modest and uncertain merger seeks to bridge the gap between the two worlds. It is intended to bring modern technological tools to the artist for creating new art forms and fresh insights and viewpoints to the engineer for creating a "people-oriented" technology.

The event was celebrated at a news conference "happening" in the six-story loft building at 381 Lafayette Street used for studio purposes by Robert Rauschenberg, the avant-garde artist.

Kheel's 'Biggest Mediation'

Mr. Rauschenberg, along with Dr. Billy Klüver, an electronics engineer who is specializing in laser research at the Bell Laboratories, and Theodore W. Kheel, the lawyer-labor mediator, are prime movers in the art-technology merger.

"For me," said Mr. Kheel, "this is the biggest mediation I've ever undertaken."

Among the art objects on display was a large drawing of a nude generated by a computer. Masterminded by two engineers, L. D. Harmon and K. C. Knowlton, this project involved the making of a transparency from a photograph and scanning it with a device operating like a television camera.

The information on the transparency was then stored on magnetic tape in the form of pulses standing for digits, with the brightness level of the picture elements represented by numbers ranging from 0 to 7. After processing all the numbers, the computer printed a drawing of micropatterns formed by clusters of symbols used in electronic design.

Visitors at the studios were intrigued by a sculptural representation of a woman taking a shower. As droplets of water dripped from the shower-head in a white stall, moving-picture images of the woman were registered by a projector behind the stall on a sand-blasted Plexiglass panel.

Rauschenberg's 'Oracle'

Another sculptural construction was a sound-emitting assembly consisting of a tire, truck door, window frame, bathtub and air vent. This is Mr. Rauschenberg's "Oracle."

Five radios are used, with the tuning dial of each being rotated by motor. Thus, each radio picks up snatches of the broadcasts of all the local radio stations. To eliminate wiring from assembly components to the central pick-up point, signals from the radios are relayed to the components by small FM transmitters.

Last year an artist-engineer collaboration called "Nine Evenings: Theater and Engineering" left the art critics bewildered. A few visitors at the Lafayette Street show also looked with puzzlement on "Oracle." But the show sponsors emphasized that it was the idea of collaboration, and not a specific art work, that counts most.

Contributions Are Listed

While 20 helium-filled pillows floated eerily in a two-story room called "the Chapel," the need for bringing artist and technologist together was stressed in speeches by Senator Jacob K. Javits, a traditionalist who sees merit in modern art; Ralph C. Gross, president of the Commerce and Industry Association; Edwin Langsam, film projection supervisor of the American Telephone and Telegraph Company; Herman D. Kenin, head of the A.F.L.-C.I.O.'s new Scientific, Professional and Cultural Employes Council, and Dr. Warren Brodey, a psychiatrist, of the Massachusetts Institute of Technology.

A.T. & T., the International Business Machines Company, the Atlantic Richfield Corporation and various labor groups are among the organizations that have made $1,000 contributions for furthering the cooperation between artists and engineers. But Mr. Gross urged industry to enlarge "the less than 3 cents of each corporation-contribution dollar that goes to the arts."

"Along with its obligation to be a profit-maker for its owners, the modern business corporation has an obligation to be a good citizen in the community," he said. "As a basic part of this obligation, the corporation must examine carefully its responsibility to support the arts."

In explaining the unions' interest in art and engineering, Mr. Kenin, who is head of the musicians' union, said that union members were concerned about a "growing chasm" between disciplines, the "growing impersonalization" of work and the frustrations faced by many individuals in seeking to make "valuable contributions."

He noted that union members were also consumers, members of audiences and citizens concerned with the quality of society.

The event served to dramatize a drive to win organizational support for the art-technology merger and to mark the transfer of Experiments in Art and Technology, Inc., a nonprofit organization of artists and engineers, to the new Automation House being prepared at 49 East 69th Street.

Automation House will be the center of the American Foundation on Automation and Employment, headed by Mr. Kheel and concerned with human problems caused by automation—notably the problem of individual "isolation."

Dr. Brodey, who heads M.I.T.'s science camp for underprivileged youngsters, noted that new technologies had opened large new areas of creativity. While the industrial revolution "averaged the people," he said, the great strides made in science and engineering had opened "a new potential for living in a personalized environment if we merely can think our way out of the old mass-production mentality."

He added:

"It is the artist who has the capacity to make personalized products that grow in meaning as they become more familiar. The artist has learned to use as his material the familiar that is outside the 'accepted system.' By his slight shifts, relevance and meaning emerge from the hackneyed."

Dr. Klüver, the laser specialist, stressed his belief that the art-technology merger should primarily be aimed at "catalyzing the individual's responsibility for the shaping of the new technology." In pursuing this end, the 40-year-old scientist, a thin, blond man who came here from Sweden in 1954, has long assisted artists in developing new modes of expression.

A Natural Marriage

He has advised sculptors on how to build self-exploding contraptions, helped painters add neon lights and motors to their works, and provided them with amplifiers, oscillators, speech synthesizers, image producers and various kinds of electronic detectors to extend their range. To Dr. Klüver, it is a natural marriage.

Technology supplies new materials, new techniques and new imagery to the artist. In return, technology gets from the artist new outlooks that make it "more human, more reasonable, more varied, more lifelike, if you wish."

Robert Rauschenberg, the 41-year-old soft-spoken ex-Texan who has been called an artistic enfant terrible, agrees that technology has bountiful gifts to offer the artist. Far from fearing it, he finds it an "exciting challenge."

'No Place Is Safe'

"If you don't accept technology you better go to another place because no place here is safe," he said. Asked what made technology so exciting for him, he replied: "Nobody knows the kind of art that will be created if two or three men in diverse fields become collaborators."

About 370 artists already have written to Dr. Klüver and Mr. Rauschenberg seeking technical assistance for projects they have in mind. The letters include requests for information on synthetic fabrics, pigments, enamel finishes, translucent spheres, micro-organisms, electromagnetics, "slow chemical destruction of objects," "extending the range of sensory perception" and an "efficient way" to make paintings appear and disappear.

Mr. Rauschenberg himself has a project in mind with problems that he has not yet been able to solve technically. He envisages a room "that would be responsive to weather, to people viewing it, to traffic, noise and light."

This he sees as the art of the future.

"Nobody wants to paint rotten oranges anymore," he said.

The New York Times (by Neal Boenzi)

Dr. Billy Klüver, electronics engineer specializing in laser research, arranges helium-filled pillows.

Drawing of nude above was generated by a computer under direction of L. D. Harmon and K. C. Knowlton, engineers. Black square encloses the detail shown.

Senator Jacob K. Javits speaking yesterday at gathering at 381 Lafayette Street. A traditionalist, the New York Republican nevertheless finds merit in modern art.

Robert Rauschenberg, the artist, says, "If you don't accept technology, you better go to another place."

Figure 5.2 *New York Times*, October 11, 1967, with *Nude or Studies in Perception I*, made by Bell Labs engineers Kenneth Knowlton and Leon Harmon. Also featured in the piece are Robert Rauschenberg (quoted as saying, "If you don't accept technology, you better go to another place"), Senator Jacob. K. Javits, and Billy Klüver, who is shown with the *Silver Clouds* he made with Andy Warhol.

At an accompanying press conference, Theodore Kheel branded the seemingly odd association of engineers, artists, and organized labor as "the biggest mediation I've ever undertaken." Standing alongside Senator Jacob Javits, he noted that "with the rapid advance of automation, the individual worker is becoming lost and compressed." Kheel continued, "Art is an expression of individualism and it deserves a place in the factory and the office," noting that E.A.T. and the American Foundation on Automation and Employment shared "similar objectives."[61] Each group wanted to provide people with "new opportunities for self-improvement."

Klüver and Kheel highlighted the fact that E.A.T. would be sharing space in the yet-to-be-finished Automation House, which the *Wall Street Journal* referred to as a "laboratory" that would "deal with job dislocation."[62] As E.A.T.'s future headquarters, it would boast "the latest in audio and projection equipment" for "experimental work, seminars, and performances," along with access to "information retrieval equipment," a "microwave tower" for transmitting television broadcasts, and possibly even a small computer.[63] The AFL-CIO signaled its approval of the new alliance with a cartoon in its weekly newspaper that circulated to tens of thousands of union members. A sturdy-looking man, identified as "Organized Labor," was portrayed giving a wink and a big thumbs-up as he stood in front of a movie theater with "Union-Supported Cultural and Arts Activities" on the marquee.[64]

As hostesses in slit-sided miniskirts silkscreened by Rauschenberg moved about his spacious studio, labor leaders from groups like the American Federation of Musicians and Bell Labs' John Pierce praised the new coalition. Taking the podium, Klüver described artist-engineer collaborations as a new way to "catalyze the individual's responsibility" for new technologies.[65] By enriching people's appreciation of technology, the "distinction between work and leisure" might be eliminated (a surplus of leisure time was an oft debated topic for sociologists who predicted a more efficient postindustrial society). Collaborative art making remained, Klüver believed, a tangible means to create better public awareness and responsibility about technology.

Despite Klüver's insistence that E.A.T.'s goals transcended making art, reporters and art writers still eagerly sought artists' opinions. Robert Morris—although not affiliated with E.A.T., he had worked with Carolee Schneemann and was briefly married to Simone Forti—offered one such perspective. As an artist who had started incorporating industrial materials into his minimalist sculptures, Morris observed that art making was now "less and less a matter of being in a studio." Now, the typical artist's day included "making appointments, visiting factories, and gathering information." E.A.T., Morris suggested, expanded opportunities for artists by offering much-needed logistical and technical help.[66] Rauschenberg's comments were less circumspect. Art mixed with technology simply was "the future" and artists who ignored technology did so at their own risk. "Nobody," he stated as Warhol's shimmery silver pillows floated lazily about his studio, "wants to paint rotten oranges anymore."[67]

AVOIDING THE WASTE OF A CULTURAL REVOLUTION

At the coming-out party, Klüver and Rauschenberg presented a bold vision for E.A.T.'s future. Condensed onto a single sheet of paper, their words were set against a gentle bluish background of sky and clouds that the artist had made. Besides maintaining a "constructive climate" for "civilized collaboration" between artists and engineers, E.A.T., echoing Klüver's long-standing personal aims, would "eliminate the separation of the individual from technological change" while also seeking to "expand and enrich technology." Rauschenberg contributed an even more provocative goal. As a conduit that brought artists, engineers, and industry together, E.A.T. would try to "precipitate a mutual agreement" between diverse stakeholders. Finally, they included the bold claim that bringing engineering and artist communities together could "avoid the waste of a cultural revolution" that seemed to be taking place all about them.[68]

Saying you wanted a revolution certainly resonated with many people's attitudes in the late 1960s. Mass protests, tragic assassinations, campus uprisings, and disobedience (civil and otherwise) coalesced. E.A.T's advocates, in keeping with the tumult of the times, often invoked their own form of "revolution-speak." In promoting his organization, Klüver often mentioned the importance of fostering disruption and transformation. "We say that E.A.T. is a revolutionary idea rather than a cultural and educational problem," Klüver told one executive at an arts foundation, "we are trying to bring about a discontinuity in the present state of affairs."[69]

The transformative power of collaboration caught the attention of corporate executives. Soon after the party at Rauschenberg's, Frank Stanton, the long-serving president of CBS, traveled to North Carolina to address the state's art community. Stanton, who knew Klüver via Marian Javits, noted how modern art was beginning to reflect the "new scientific thinking of our time . . . a change from an art of perception to an art of conception." He recalled how he had recently traveled to Paris where he saw "a truly remarkable exhibition" titled "Lumière et Mouvement."[70] Curated by Frank Popper and hosted at the Musée d'Art Moderne, it featured such electro-kinetic artists as Nicolas Schöffer, Jean Tinguely, and Frank Malina. The show convinced Stanton that art was rapidly becoming “a mixed media affair” as all sorts of new materials and technologies were becoming available. To help the contemporary artist “become acquainted with the laboratory, the foundry, the plastics shop, the factory,” Stanton encouraged fellow business leaders to support both E.A.T. and the idea of artists-in-industry.[71]

But Klüver’s cultural revolution still needed more willing professional engineers while also sidestepping “those [engineers] who want to be artists.”[72] Obstructions to recruiting more of the former ranged from the private to the prosaic: “misinformation about the artist, personal aesthetic hang-ups, a wife that paints” to “intimidation by superiors and a front lawn to cut.” Although E.A.T.’s vision might appear somewhat quixotic today, recall that industry’s demand for trained engineers remained exceptionally strong while companies were keen to provide amenities in order to retain valuable researchers and technical staff. If this meant allowing interested engineers to interact with artists during working hours, Klüver reasoned, middle management would cooperate. Buoying his confidence was the fact that the American economy continued to boom. Unemployment remained well below 4 percent, inflation was largely under control, and the gross national product surged toward $800 billion. American companies should and could afford the cultural revolution that E.A.T. offered.

Klüver remained mindful of the need to tolerate failure as part of his larger wish to confront the nature of technology. “Everyone knows that technology fails,” he observed, “but people do not really know it bodily.” Gallery owners and curators may “get the jitters if things fail,” while research engineers, who were comfortable with botched experiments happening in the privacy of the lab, might be “more cautious, less inventive” if their public reputations were at stake. (The technical glitches and mishaps of *9 Evenings* had taught everyone a tough lesson on this point.) Nonetheless, taking creative risks was needed because “if we cannot have technology that fails, we can have no exploration.”[73]

Just as Klüver was neutral on whether engineers needed to understand the intricacies of modern art, there was also the reciprocal question of how much engineering the contemporary artist should know. In January 1968, when the College Art Association met in Saint Louis, Klüver and art critic Lawrence Alloway organized a panel. Called “Collaborative Projects between Art and Engineering Students,” it reexamined the type of university courses taken by both engineering and art students. Alloway was intrigued to see so much attention at the meeting given to art-and-technology topics, including panels on computer graphics and intermedia. He interpreted the situation as a modern realization of *Gesamtkunstwerk*, the nineteenth-century German ideal where many forms of art are brought together and synthesized (as in a Wagnerian opera). Recognizing that "technology has enlarged the possibilities of collaboration," Alloway imagined that future art students would likely have to learn much more about technology or else they would become professionally dependent on engineers.[74]

Alloway's recommendation coincided with a new project that E.A.T. had started. In February 1968, the group hosted a series of evening lectures "designed to expose areas of contemporary technology for artists."[75] Klüver and his colleagues recruited an impressive lineup of experts from labs and universities all along the East Coast. From Max Mathews and James Tenney, for instance, one could learn about computer music, while Kenneth Knowlton and Stan VanDerBeek contributed to a four-part series on computer-generated images. Aspiring artists had the opportunity to experiment with new polymeric materials, hear lectures on lasers and holography, or get an introduction to computer-generated speech. E.A.T. taped all the lectures for those who couldn't attend and, for artists who wanted more technical information, it compiled an extensive list of libraries with relevant books and journals. In all, E.A.T. had hosted more than thirty lectures, adding pedagogy as another element in the cultural revolution that Klüver and Rauschenberg sought to provoke.

Following through with pronouncements made when E.A.T. joined with Kheel and Automation House, the group also announced a new partnership spearheaded by Rauschenberg and the head of Local One of the Amalgamated Lithographers of America. The union's nearly 10,000 members were skilled in the craft of printing and graphic arts but their workplace was on the frontline of future automation. The plan was to build an experimental space, named The Quarry, where artists could collaborate with the union's technicians. In exchange, printing shops could expect to attract new orders from businesses with "unusual printing needs." The union's leader described the effort as a "marriage between the Venice Biennale and Local One" that gave artists an opportunity to "explore the technological resources" modern printing shops offered.[76]

Media coverage about E.A.T. in the United States and abroad proliferated as interest in the group's distinctive strategy for advancing the art-and-technology nexus continued to grow. E.A.T.'s staff compiled a collection of relevant articles that ran more than forty pages long, which was shared with potential patrons. *Art in America* added to this growing literature with its special issue on the art-and-technology wave. In it, art critic Douglas M. Davis, riffing on Rauschenberg, branded the cultural merger of engineers and artists as the "New Combine."[77] As one art writer reflected, "technological art seems to generate some very human reactions."[78] While the art-and-technology movement might "outrage the old-line humanist and the art-for-art's sake critic," artists' new partnership with engineers was "endowing art with an element of play" even as it "incontestably de-emphasizes the hand and therefore craft."[79] On the other side of the alleged cultural divide, technical journals such as *Machine Design* and *Product Engineering* noted approvingly how "things technical" were the new "wellspring for inspiration," while "the engineer is becoming 'in' with the art crowd." Once viewed as "Philistines," engineers were now as welcome in studio lofts and galleries as "prospective patrons and Expresso coffee."[80]

As E.A.T.'s visibility increased, so did the numbers associated with it. A steady stream of inquiries kept E.A.T.'s staff—now up to about half a dozen full- and part-time employees—busy fielding daily inquiries. Total membership had grown to as many as 4,000 people and the print run of E.A.T.'s newsletter regularly topped twice that. Early in 1968, the organization reported that some 300 engineers and 700 artists had actively expressed interest in joining a working collaboration and E.A.T. brokered at least one new pairing a day. To help manage its matchmaking efforts, E.A.T. implemented an index card-based system, which allowed staff members to record engineers' technical expertise and pair this with artists' needs. The result was an extensive database—containing thousands of paper cards—that could be manually sorted to generate pairings of individuals as well as targeted mailing lists. Interest in E.A.T. spread as artists and engineers throughout the United States as well as in Canada and even a few locations in Europe asked about establishing local chapters.[81] The main locus of organizational activity, however, remained in New York (as reflected in office stationary with "E.A.T. Central" on the letterhead) where Klüver and his associates offered advice and encouragement.

Despite the sustained burst of interest in E.A.T.'s approach to art and technology, however, its goals and funds remained mismatched. Two awards—$50,000 from the National Endowment for the Arts and $25,000 from the Rockefeller Brothers Fund—provided some relief and gave E.A.T. a much-needed validation while the group solicited larger amounts from other philanthropic foundations. In doing so, Klüver and E.A.T. began looking more intently beyond the confines of the art world. As he told the director of the Ford Foundation, "our organization has less to do with promoting the aesthetics of art than with social change."[82]

E.A.T. started to explore how partnerships between artists, engineers, and other communities might catalyze "cultural revolutions" in areas that had little to do with avant-garde art. As he commuted between New York City and Bell Labs, Klüver could see firsthand the results of violence caused by social and economic inequality. During the long, hot summer of 1967, for example, unrest flared up in nearby Newark, New Jersey when two white police officers brutally assaulted an African American taxi driver and then arrested him on false charges. Over the next four days, armed police officers and national guardsmen violently clashed with the primarily African American residents of Newark, leaving more than two dozen people dead (the majority of whom were civilians) and millions of dollars of property damaged or destroyed during the protests and riots.

In the midst of this unrest, Klüver sensed a new opportunity for collaboration. One of the groups that visited E.A.T.'s loft in 1968 was Real Great Society, a collection of activists and organizers from the Puerto Rican community that formed in 1964 as a response to gang violence.[83] The meeting prompted Klüver to consider how E.A.T.'s focus on partnerships might be extended to bring engineers and scientists together with "groups in the ghetto." Technology, he insisted, did not have to be a "vehicle for repression, uniformity, and control of the individual." Moreover, technical activities could "promote agreements between individuals" as they came together to reform technological systems and build new ones. As a result, technology could create "imaginative and innovative" interactions between "the individual from the ghetto and the specialist from the technical community." By offering inner-city residents a "challenge of their own to create an environment," the results might be "applicable to the rest of society." Urban, disenfranchised communities, in other words, could be laboratories for social and technical experimentation, an idea he proposed (unsuccessfully) as a potential new research program to his supervisors at Bell Labs.[84]

Although naïve, Klüver's views were not uncommon among technologists eager to apply their skills to social problems of the 1960s.[85] In a letter to a highly placed engineer on the National Research Council, he proposed building mobile diagnostic clinics linked to a central computer and closed-circuit television systems designed for "the ghetto or a village in India."[86] In stressing the need to collaboratively develop "alternate technologies" for "industrially deficient environments," Klüver's thinking reflected ideals of the "appropriate technology movement" promoted by social activist groups in the 1960s.[87] And, in questioning the autonomous nature of technology, Klüver's ideas echoed those expressed by public intellectuals like Lewis Mumford, concepts which later coalesced under the academic banner of "science and technology studies."

Nonetheless, Klüver insisted his ambitions remained anything but utopian. "I can make no claim about the importance of the art and technology collaboration," he told critic Douglas Davis. "It will not give people food and housing," he warned, "and it will not stop the war in Vietnam."[88] As 1968 began, E.A.T. had secured a place at the forefront of the art-and-technology wave. But the power of art and technology, creative collaborations, and E.A.T. itself all had limits and these would soon be tested.

6

SURGES

> Steadily we move toward a “scientific artistry,” one that rejects whatever is inconsistent with contemporary science. . . . It is the nature of cultural revolutions that we outwardly eschew their values while accepting them inwardly.[1]
>
> Jack Burnham, 1968

If you are ever caught in an elevator with some historians and want to entertain yourself while the fire department responds, ask them which year was *the* most important. It’s the sort of question that can get them arguing long into the night. But it’s not hard to make the case that 1968 was an especially significant year in a century replete with contenders.

During those 366 days (1968 was also a leap year) the chaos kept churning: 1968 was Khe Sanh, Tet, and My Lai; it was bras, draft cards, neighborhoods, and hamlets all going up in flames; it was the horrific assassinations of Martin Luther King and Robert F. Kennedy; and it was the year Valerie Solanas shot and wounded Andy Warhol and Mario Amaya. And, in the midst of all this turmoil, avant-garde pioneer Marcel Duchamp died of a heart attack in his studio outside Paris.

Around the planet, millions of disaffected young people, workers, and underrepresented minority groups rebelled against authority figures.[2] Frank Malina’s oldest son, Roger, hung out with other *soixante-huitards* at the Sorbonne only to be accidentally tear gassed as he roamed Paris scouting for groceries. Chinese Red Guards advanced Chairman Mao’s Great Proletarian Cultural Revolution, Warsaw

Pact soldiers crushed the Prague Spring and, in Mexico City, troops killed hundreds of protesting students just days before two African American athletes raised defiant fists in the Black Power salute at the Olympic Games held there. Astronauts may have sent back images of a planet delicately floating in space, borderless and calm, but, on the ground, the whole world seemed engulfed in division and anger.

Compared to struggles by women and underrepresented minority communities in the United States, and once-colonized peoples elsewhere in the world (not to mention the millions affected by the conflict in Southeast Asia) the art-and-technology movement pales in significance. No one was beaten, blasted with firehoses, or killed for making art. Jail time was limited to isolated incidents, such as when Nam June Paik and Charlotte Moorman, two avant-garde artists Billy Klüver knew, flaunted local obscenity laws. And yet the era's larger societal upheavals provided the context, sometimes even the motivation, for artists and technologists to collaborate in the first place. As we've already seen, E.AT.'s advocates believed that creative collaborations could transcend art to allay workers' fears about automation and address the needs of the urban poor. The tendency of many art-and-technology participants to not engage with what was happening around them would prove equally important.

The year marked a critical inflection point for the art-and-technology wave of the 1960s. Based on the volume of articles in newspapers and magazines, popular interest in "tech art" (one of many critics' terms that proliferated) peaked in the United States and elsewhere. Exhibitions of art and technology, ranging from extravagant productions at the Museum of Modern Art in New York to more modest presentations in places like Zagreb and Kansas City, fueled the curiosity. Some of these efforts reflected the zeitgeist of 1968 as artists and engineers, especially in Europe, saw their collaborations as part of intellectuals' larger critique of technocratic capitalism. In other cases, the merging of art and technology was tied to corporate interests and, remained consciously or not, apolitical.

In 1968, the infrastructure for art and technology also dramatically expanded. In Paris, Frank Malina brought his personal interests in art, technology, and science to a wider community with the first issues of *Leonardo*. Several other publications surveying art and technology joined Malina's journal on library shelves and coffee tables that year. Back in the United States, meanwhile, Gyorgy Kepes (who we met briefly in chapter 2) pursued a different strategy. Eager to create a community akin to the prewar Bauhaus, his Center for Advanced Visual Studies was formally dedicated in March 1968 at the Massachusetts Institute of Technology. (Klüver spoke at the ceremony while Malina considered spending time there as a visiting fellow.)[3] Like E.A.T., Kepes's initiative offered a "testing ground" where visiting artists and technologists could engage one another and collaborate on projects and exhibitions.[4]

Malina, Klüver, and Kepes occasionally corresponded or met in person but each independently pursued diverse stratagems for blending art, technology, and science. Their personal backgrounds—Malina was an American based in Paris with strong ties to Czechoslovakia, while Klüver and Kepes had emigrated to the United States from Europe—and the social networks they cultivated point to a larger characteristic of the art-and-technology movement. Just as activism and protests sparked up and spread from cities such as New York, Stockholm, Paris, and Prague, surges of interest in art and technology were international as well as interconnected. It is not unreasonable to picture the art-and-technology movement, circa 1968, as a global community of sorts with hundreds of artists, engineers, and scientists participating along with scores of institutions, museums, and patrons.

Given the varied locales from which this enthusiasm surged, it's not surprising that it embraced and expressed diverse perspectives and political ideologies. Whereas E.A.T. actively sought funds from American corporations, participants in the *Nove Tendencije* (or, New Tendencies) movement, centered around Zagreb in Croatia, saw the confluence of art and technology as an opportunity to critique technocracy and the increasing computerization of modern society it fostered.[5] While their work was steeped in philosophy to degrees that the pragmatic members of E.A.T. would have found unappealing, all of these art-and-technology initiatives shared a common fascination with computers and art. Closely coupled to this was a deep interest among both artists and engineers in information science and systems thinking. Cybernetics had emerged out of World War II as an interdisciplinary science based around concepts of communication and control.[6] By the 1960s, however, its underlying ideas had migrated well beyond their original Cold War borders and taken root in art journals and international art exhibitions.

This chapter explores how this global burst of excitement for art and technology manifested itself via a surge of activity in three areas: publishing, institution building, and exhibiting. This trio reflects an inherent logic. In *Leonardo* and other publications, art exhibitions were frequent topics for examination and critique while art shows, of course, were accompanied by informative and sometimes quite creative catalogs. Meanwhile, new organizations like CAVS looked to make their mark via exhibitions and written works. Permeating all of these undertakings, like some ambient electrical field, was the adoption and deployment of innovative new information and computing technologies as the artists' world was swiftly being rewired and electrified.

GIVING THE "MUTE ARTIST" A VOICE

Running a scholarly journal presents an editor with a seemingly never-ending list of tasks. As *Leonardo*'s editor-in-chief from 1968 until his death in 1981, Frank Malina recruited authors who ideally would submit a steady flow of high-quality submissions. These, in turn, had to be reviewed by Malina and refereed by outside readers, followed by careful editing of subsequent drafts before the final articles were published. Since *Leonardo* was an art journal, selecting the right images to accompany them was critical. Malina sometimes rewrote sections or even rejected some contributions outright, so egos had to be assuaged. Then there were issues of budgets and schedules. The thousands of archived pages of *Leonardo*-related correspondence with people from around the globe attest to the time Malina invested in his new venture. (It also explains the decline in his artistic output. In 1968, he made over 100 works; this dropped to seven the next year.)

When he first launched *Leonardo*, Malina could draw on a reservoir of experience as an engineer, artist, and author. As an artist, Malina might have worked mostly unaided but starting and maintaining an international journal required much more extensive collaboration. By 1968, Malina had built an extensive roster of personal and professional connections that he could call upon for advice and ideas. Financially secure, he could afford to operate *Leonardo* with a degree of freedom unfamiliar to many other journal editors. Finally, Malina had a powerful friend and ally in the form of Robert Maxwell whose company, Pergamon Press, published *Leonardo*.

Like Malina, Maxwell had family roots in Czechoslovakia. After the Nazis came to power—much of his family died in the Holocaust—the teenaged Maxwell escaped to France and volunteered for the French Foreign Legion. Physically imposing and compulsively active, Maxwell soon made his way to England where he enlisted with the British Army and rose to the rank of captain, a title he would use throughout his life. After World War II ended, Maxwell went to work for a joint British-German publishing firm. In 1951, when the company began having financial difficulties, Maxwell bought it. Rebranded as Pergamon Press, Maxwell's venture commenced to unsettle the normally staid world of scholarly publishing.

His entry into the business could not have been timed better. In the 1950s, the scientific community was booming in size while researchers' increased specialization created a market for hundreds of new journals. Established titles helped bootstrap new ones. Pergamon increased its portfolio size and profitability even more by offering cover-to-cover translations of leading Soviet scientific periodicals. By the 1960s,

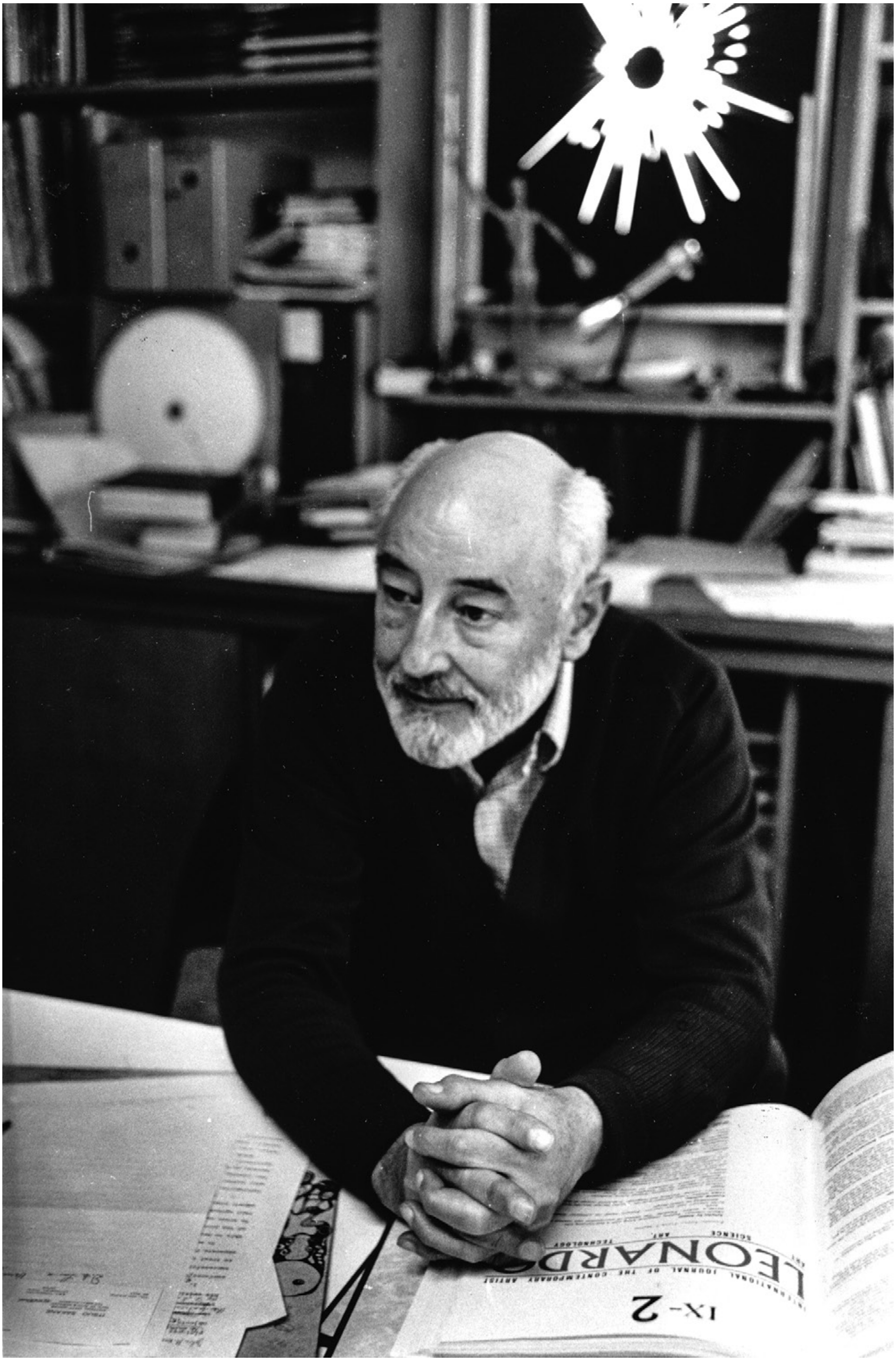

Figure 6.1 Frank Malina with early issues of *Leonardo*, ca. 1978. Hanging behind him is his 1970 lumidyne, *Pax III*. Image courtesy the Malina Family Archive.

with journal circulations growing by as much as 10 percent annually, Pergamon Press had become one of the world's leading scientific publishers and it had made Maxwell very wealthy. Elected to the British Parliament in 1964, biographers later alleged that Maxwell, an ardent Zionist, was also connected to the highest levels of the Israeli government. (These claims received fresh scrutiny after he drowned off his luxury yacht, the *Lady Ghislaine*, in 1991 as his business empire was collapsing.)[7]

Frank Malina first met Robert Maxwell in 1958 when the publisher was in Paris for a scientific meeting. Soon, correspondence between "Dr. Malina" and "Capt. Maxwell" gave way to "Frank" and "Bob." Maxwell was particularly taken with Malina's electro-kinetic works and later commissioned Malina to make *The Cosmos*—the massive lumidyne described earlier—as the centerpiece of Pergamon's headquarters in Oxford. It was, in fact, while he was building this artwork that Malina broached the idea with Maxwell for a new journal "directed at working artists in the field of the visual arts," as well as researchers interested in "scientific aesthetics." As Malina pitched it, his publication would "stay clear of 'classicists' and 'humanists'" and avoid verbosity from denizens of the "gallery and museum world." This was to be, in other words, a journal for practitioners, not critics.

To get the project moving, Malina convened a small group of like-minded people to develop the idea.[8] The list of names he proposed to Maxwell reveals the diverse communities in which the engineer-turned-artist now moved. In addition to Gyorgy Kepes, Malina included Jacob Bronowski, a mathematician who knew Malina from their time together at UNESCO. Besides writing popular articles about creativity, he was developing what later became the hit BBC television series *The Ascent of Man*.[9] Claude Berge, a mathematician who had cofounded the French experimental literary group Oulipo (shorthand for Ouvroir de littérature potentielle or, roughly, "workshop of potential literature"), was also on Malina's roster. Anthony Hill had started his art career in the late 1940s as an abstract painter but, by the time Malina reached out to him, he had a second career as a mathematician. A leading member of the British constructivist movement, Hill was keenly interested in applying mathematical theories to art making. Malina also included two American colleagues. Alfred L. Copley was a German-born research physiologist but no stranger to the New York art scene. He painted professionally in New York under the name L. Alcopley, participating in the famous 9th Street show in 1951 that helped the city's avant-garde scene get a toehold in the mind of critics and the public. Meanwhile, Gerald Oster, a chemistry professor at the Polytechnic Institute of Brooklyn, was especially interested in questions of visual perception. In addition to writing about moiré patterns, a phenomenon Malina had exploited in his early art experiments, Oster had recently displayed his optical art at Howard Wise's gallery in New York.

Malina's intellectual and social community was quite different from Billy Klüver's. Although they were born just fifteen years apart, the span was significant. The Depression greatly shaped Malina's personal views while many of his sensibilities in art reflected the 1930s. Klüver, meanwhile, joined Bell Labs during a period of unparalleled professional opportunities for engineers. Where the paranoia of the Red Scare influenced Malina's path to the art world, the technological advances and economic boom that marked the long 1960s molded Klüver's experiences (with the growing conflict in Southeast Asia adding a discordant and increasingly dominant note once E.A.T. was under way).

There were few commonalities in terms of either scientists or artists with which the two men associated. Where Klüver was very much grounded in the American art and engineering scenes (while maintaining strong ties to his native Sweden), Malina's extraordinarily diverse network of international correspondents stretched back to his days as a graduate student at Caltech. As he promoted *Leonardo*, Malina could, for instance, appeal for support to people like Frank Oppenheimer. In 1968, Malina's former classmate had presented detailed plans to community leaders in San Francisco for a new venture that would "demonstrate the ties between man's senses, the development of art forms, scientific exploration, and technological development."[10] Dubbed the Exploratorium, its emphasis on explaining visual and audio phenomena resonated with Malina's long-standing interests in the psychology of perception.

Malina's exile in Paris, meanwhile, had familiarized him with a particular and self-selected community of artists. Around 1960, Yves Klein and Vassilakis Takis, two avant-garde artists living in Paris, had a celebrated feud over claims of artistic theft. There is no indication in Malina's writings that he paid it any attention whereas Klüver was personally known to both artists.[11] Malina, in fact, suggested that Jean Tinguely's art could "not be recognized on a junk heap," disparaged Duchamp's readymades, and expressed reservations about the quality of Rauschenberg's work.[12] Malina and Klüver might both have been trained as engineers but they possessed quite different tastes in art.

Malina especially liked to associate with people who had demonstrated accomplishments in science as well as the arts and humanities. In fact, it was his colleague, biochemist-turned-historian Joseph Needham, who he knew from his time with UNESCO, who proposed *Leonardo* as the name for Malina's journal. Later, both Needham and C. P. Snow agreed to be listed on the journal's masthead as "Honorary

Editorial Advisors." In addition to having interests that spilled across cultural and disciplinary divides, the men Malina corresponded with were all curious about common themes that art and science shared. Whereas Klüver insisted that the working worlds of artists and scientists had little, if anything, in common—"What would they talk about?," he once remarked, "ESP? The beauty of the stars?"—and focused on fostering practical collaborations between artists and engineers, Malina believed that making art and doing science had at least *something* in common.[13]

In fact, at the same time as he discussed his idea for a journal with Robert Maxwell, Malina was finishing an essay that compared science and art.[14] Over the various drafts Malina sent to colleagues, one finds several core themes that later informed his opinions as to what his new art-science journal should offer. The chief purpose of science, Malina reasoned, was to allow people to predict the "future behavior of well-defined aspects" of the world. Art, meanwhile, existed to "satisfy human emotions" and to "deepen emotional perception" of the world. Malina's professional experiences led him to conclude—here, he referenced recent attempts to study and even quantify creativity—that the "creative process is basically similar" for art and science despite the different goals. However, if the "theoretical basis of art is the concern of aesthetics," he wrote, "the practicing artist finds this branch of philosophy about as useful as meteorology is at the present for predicting the weather a month ahead."[15] Like the sounding rockets he had once built, certain kinds of art could probe the nature of human perception. And, just as he had once applied basic scientific principles to rocket propulsion, Malina imagined a similar approach might one day explain how people saw, perhaps even improving the process of art making itself. A half century later, researchers were indeed publishing empirical studies on the relation between cognition and affect in the arts. And Malina would have certainly been intrigued with research that quantified "reputation and success in art" in terms of networks, studies that likely also would have confirmed his suspicions of personal biases in the art world.[16]

Malina extended his analysis of art and science as modes of inquiry to include the accepted practices and behaviors within the two communities. For example, through conference proceedings, technical memos, and journal articles, engineers and scientists presented a formal record of their work. In comparison, artists relied on theorists, aestheticians, and journalists to interpret, via "second-hand reports," what they had done and how they did it. Moreover, these art critics produced "exhortative literary efforts" full of pretense rather than clear and concise statements.[17] Malina wasn't alone in this judgment. Writer Brian O'Doherty remarked as early as 1963 that the “main threat” to modern art was the “strangling undergrowth of verbal redundancies” deployed by overspecialized and “eager pedants.”[18]

Simply put—Malina’s diagnosis was that artists, if not the larger art world, would benefit if they just acted a little more *like scientists*. This view, of course, was at odds with Klüver’s as he had no interest in converting artists into engineers (or vice versa). For Malina, a solution to the problem was a journal where artists would write firsthand accounts of their experiments and describe what they were trying to accomplish and what had worked. As more artists contributed articles, they would have a growing professional literature they could refer to.

Like Klüver, Malina believed artists genuinely wanted to take advantage of ideas and techniques from science and engineering but were held back by an art establishment “hostile to the scientific outlook.” Of course, as he told Maxwell, this created a potential market. No journals were “directed to the working artist” while the “aestheticians and art historians” who wrote for existing art journals had become “almost completely separated from contemporary artists.” Malina’s publication (“patterned after journals in physics, psychology, aerospace, engineering”) would challenge the “tradition of the mute artist.” Submissions would be judged on “their clarity, logic, and possible interest to other artists,” not their “literary quality.” As he told L. Alcopley (i.e., Alfred L. Copley), “if we cannot succeed in developing a journal for professional artists in the best scientific tradition, then I will acknowledge defeat before following in the footsteps of existing art journals.”[19]

Malina could, to be fair, afford to be so stringent as he contributed significant personal funds to *Leonardo*’s operating budget. Based on the agreement he and Maxwell struck, Pergamon provided a subsidy and the articles it published were copyrighted under the press’ name but other responsibilities were borne by Malina himself. By the end of 1968, Malina estimated he had already sunk about £2,500 of his own money into the venture, equal to about $50,000 in 2019. Although he worked with an often-changing cohort of coeditors, the journal was, to a degree uncommon in scientific publishing, his personal preserve.[20]

From the currents of editorial correspondence that flowed in and out of his Paris home, one sees Malina’s insistence on an economy of words and exactness of language. “I will not accept gibberish,” he told the British surrealist Simon Watson Taylor, “even beautiful gibberish.”[21] As an editor, Malina was dogged, if not outright dogmatic, in his strict repudiation of “obscurity, verbal barbarism” and “masturbations of jargon,” a trait he loathed in some art critics’ writings and a pattern that writer Tom Wolfe later lampooned in his book *The Painted Word*.[22]

Leonardo provided carefully worded definitions for terms that appeared in its articles. When authors used words like “energy,” “cybernetic,” “entropy,” “creativity,” and (especially) “theory,” Malina would inevitably push for clarification, a sharp-elbowed editorial process that frustrated some writers.[23] (The word “camp” taxed Malina’s preference for precision until he consulted a colleague who collected dictionaries for a hobby.)[24] At times, this stubbornness put him at odds with the larger art world. *Leonardo*’s style sheet eschewed accepted terms like “abstract art” in favor of “non-figurative art.”[25] Nonetheless, Malina forcefully maintained his vision for *Leonardo* as a journal “modeled after scientific and technical journals” with the goal of “facilitating communication between artists.”[26] In addition to including abstracts in both French and English, Malina opted initially to place authors alphabetically in each issue so as not to signal any sense of status or priority. “Even if Picasso sent us a text,” he boasted, “he would be printed in alphabetical order.”[27]

For his part, Malina believed he was helping artists acquire a valuable skill. In a self-authored article on kinetic art experiments that appeared in an early issue of *Leonardo*, Malina noted that his “tough, rational” approach to being aware of previous artist’ work was needed “if for no other reason than [future artists] need not repeat the errors I made over several years.” Here, one is reminded of Malina’s alarm when he learned of Thomas Wilfred’s work only after he started making his lumidynes. And, as more artists became credentialed professionals—“men of the world,” as Allan Kaprow might have said—Malina expected that the “publish or perish syndrome” so familiar to scientific researchers would soon become part of the art world. *Leonardo* could help prepare artists for this day by encouraging them to think and write more precisely (i.e., like scientists).[28]

Such steadfastly held beliefs cost Malina friendships with some early supporters, including Oster and Alcopley. His periodic fallings-out with colleagues and coeditors reflected how *Leonardo* often was an extension of the debates and conversations he fostered through regular gatherings in his Paris living room. While Malina’s taste in art and artists might not have reflected contemporary fashion, he remained open to points of view he didn’t agree with, provided these opinions were backed up with evidence. After meeting with Klüver in New York, for example, Malina asked him to explain (in print) what he meant when he said E.A.T. was “not interested in art but *process*.”[29] Committed to promoting open dialogue in *Leonardo*, Malina was combative but rarely censorious.

Malina and his coeditors worked ceaselessly to drum up enthusiasm for the journal and encourage manuscript submissions. In quick succession, he reached out, for instance, to C. P. Snow, Irish-British writer Iris Murdoch, and German philosopher Theodor Adorno for possible essays. It would, however, be nearly five years before Malina could claim a healthy backlog of manuscripts.[30] As Malina saw it, well-known artists were either “too old to grasp the purposes” of the journal or they were “too busy being public figures to put serious thoughts on paper.” Instead, Malina imagined it would take the new generation of art students who would “get into the habit of reading the journal and writing on their work.”[31] However, to younger artists more inclined to read about the latest shows, gossip, and disputes in venues like *Artforum*, Malina and his cohort—all born well before World War II—could, to put it frankly, seem unhip. Malina and Klüver were plugged in to very different communities of artists.

Pergamon mailed out a new issue of *Leonardo* every three months, each containing about 125 pages. Among these were color illustrations but no advertisements, a point of pride for Malina who believed that promotions for auctions and gallery shows biased, if not corrupted, other art journals. Whereas Malina could be obdurate in terms of the art he preferred—late 1960s trends toward minimalist and conceptual art were not to his liking—no one could accuse him of provincialism when it came to *Leonardo*’s authors. In *Leonardo*’s first year, artists from Sweden, Argentina, the United Kingdom, and the United States published articles. In addition, there was a memoir from a Russian-American sculptor, a book review from a British cybernetics expert, an essay by an American psychologist, and an interview with an Italian art historian. Not surprisingly, artists based in Paris were especially well represented and more than a few articles were published in French. Eventually, after some prodding, Malina secured a manuscript from Gyorgy Kepes but, despite numerous entreaties, Billy Klüver never submitted anything about E.A.T. to *Leonardo*.

What would a reader who picked up the journal find inside as she leafed through its pages? True to Malina’s interests, 1968’s print run included articles on the nature of creativity. One of these, authored by theoretical physicist David Bohm—like Malina, McCarthy-era allegations had affected his career and mobility in the 1950s—was a rather abstruse attempt to relate creativity to individual freedom. Bohm later developed his ideas into a book, with an entire chapter exploring the relationship between art and science. In the next issue, social scientist Myron Coler took a more pragmatic approach. Based on his years of research at New York University, he described how creativity had developed into a “real interdisciplinary study” and argued that, when it came to technology and their arts, there wasn’t so much “a two cultures” but “a two creatives.”[32] Perhaps more of interest to practicing artists were essays describing new materials such as liquid crystals, photochromic glass, and fluorescent pigments. Likewise, close to a dozen articles on holography appeared in *Leonardo* in its first five years, ranging from technical introductions to statements on safety issues associated with using lasers in a studio.[33]

Finally, à la scientific journals, *Leonardo* provided a public forum and information clearinghouse for activities, events, and publications related to the art-science-technology nexus. A semiregular “Documents” section presented out-of-print articles and other materials that Malina thought might “cast a new light on significant aspects of contemporary fine art.” Malina was especially keen to use correspondence from readers to fan any sparks of controversy that might boost circulation. He scored his biggest success in 1971 with an article by James J. Gibson, an American psychologist based at Cornell. Gibson’s essay, which would become one of *Leonardo*’s most cited papers, presented a new theory of “what a picture is” (versus what we see in the real world), suggesting it represented a “display of optical information.” The article, with its exploration of the differences between verbal and visual thinking, started a lively back-and-forth between Gibson, art historian Ernst Gombrich, and psychologist Rudolf Arnheim, about the nature of human visual perception.[34]

To be fair, *Leonardo* remained a modest platform for several years. By the end of 1968, Malina estimated that subscriptions had grown to around 1,000, about half of which were libraries. These numbers remained relatively steady for several years, leaving Malina genially frustrated.[35] “My experience,” he wrote, “from traveling around the world and talking to artists and art teachers leads me to the conclusion that very, very few of them read anything.”[36] Every so often, especially in its first few years, Malina became concerned that Pergamon would pull the plug on his publishing experiment. Despite occasional scares, Malina’s behind-the-scenes lobbying (plus his friendship with Maxwell) kept the journal alive and stable as *Leonardo* slowly evolved into one the most highly cited arts and humanities journals.[37]

Like Klüver, Malina tended to avoid aesthetic judgments. As Roger Malina, who took over as *Leonardo*’s editor-in-chief in 1981, explained, his father looked at the art world more from an international perspective. “The idea of a New York school and Paris school,” he noted, “as a way of structuring the art discussion was antithetical to my father.” Frank Malina was less concerned with how “good” the artists who published in *Leonardo* were and how the larger art world judged them. Of greater concern was the quality of their ideas and writing. Just as a researcher at a lesser-ranked university might make important contributions to science or engineering, so too could artists working far away from major art centers. “Posterity will evaluate the artworks" using, he predicted, "reliable criteria" from fields like perceptual psychology and neurophysiology (and not, notably, art criticism) once they became available.[38]

Malina's biggest accomplishment with *Leonardo* was establishing a mechanism to communicate with and connect a diverse community of artists, engineers, and scientists. A decade after he started the journal, Malina could claim that authors from twenty-nine different countries had published some 300 articles.[39] The latter number is pretty much what one would expect for a quarterly journal. The former figure, however, reflected Malina's genuine desire to build bridges not just across disciplinary divides but political ones. Malina believed in an ideal of cooperation and communication based on what he had experienced while working at UNESCO. Besides a forum for artists and scientists working in Western Europe and the United States, Malina's roster included authors in India, several countries in Africa, the Soviet Union, Eastern Europe, and, eventually, Communist China. *Leonardo*'s articles and steady flow of news about conferences, museum events, and gallery shows realized Malina's goal of creating an international channel of communication for people interested in and actively engaged in working at the art-technology-science nexus.

A CYBERNETIC COMMUNITY ON THE CHARLES

Malina used *Leonardo* to construct a community of artists, engineers, and scientists centered around texts and writing. At MIT, Gyorgy Kepes was working toward a similar goal but via a different avenue. With the Center for Advanced Visual Studies (CAVS), Kepes sought to re-create what he had experienced with the Bauhaus in Weimar-era Germany when he sought "agreement across a wide spectrum of disciplines—science, engineering, art."[40]

Although he and Malina pursued different strategies to reconcile the cultures and values of art and science, they shared some common viewpoints and experiences. Besides their family ties to central Europe, both men—affiliated with elite engineering schools at various times—had their artistic tastes largely shaped in the pre-World War II era.[41] Likewise, Malina and Kepes both expressed antipathy toward art trends that emerged in the 1950s and 1960s. Kepes, for instance, critiqued a variety of twentieth-century art movements, including abstract expressionism and pop art (about which Malina would have nodded in agreement) as well as kinetic and op art (one can imagine Malina's reaction to Kepes's jab at "motion-addicted artists").[42]

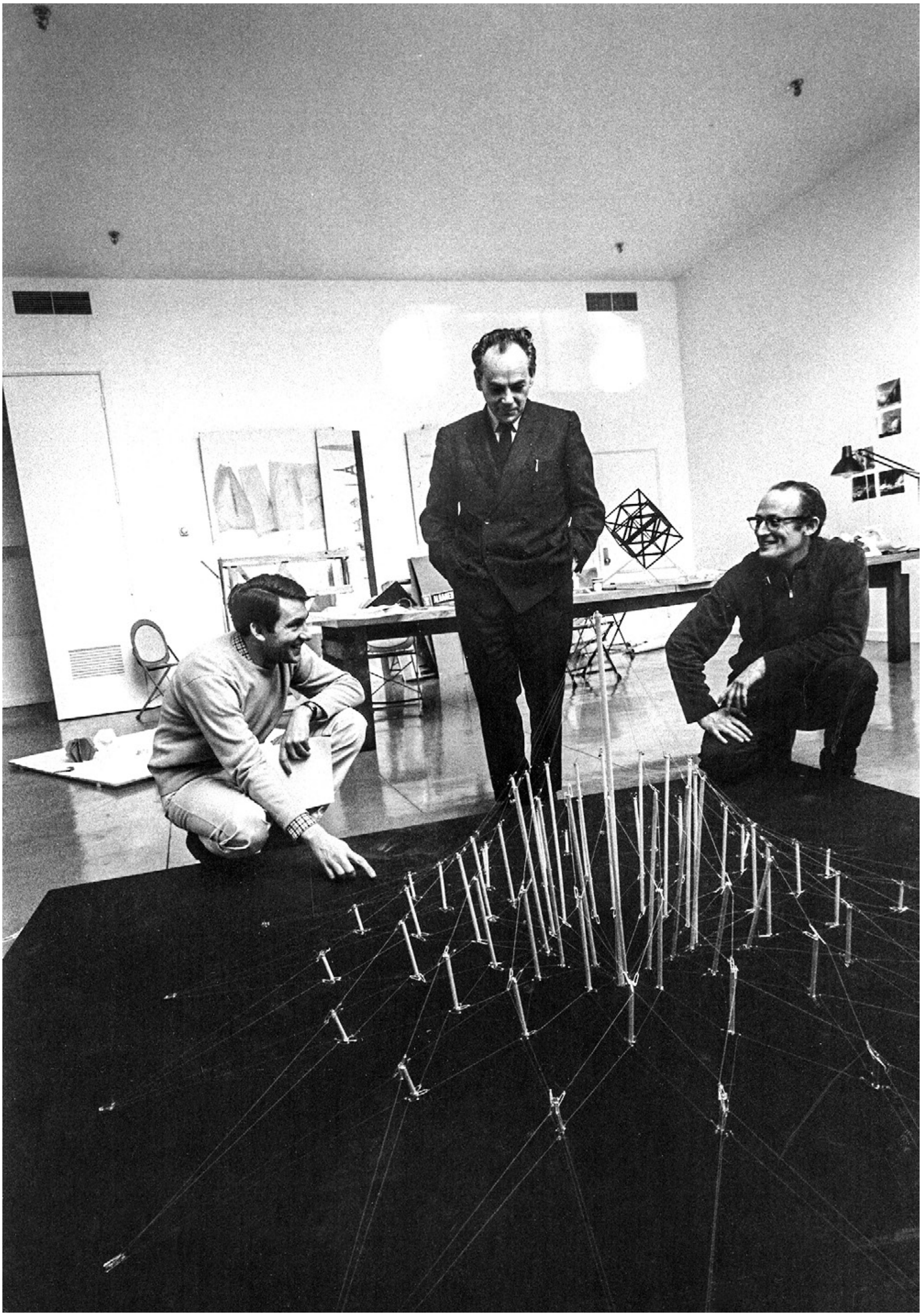

Figure 6.2 From left to right, Otto Piene, Gyorgy Kepes, and Harold Tovish at the MIT Center for Advanced Visual Studies in Cambridge, Massachusetts in 1968, soon after the center opened. Photo by Ivan Massar, courtesy the MIT Program in Art, Culture and Technology.

In terms of intellectual influences, Malina and Kepes were drawn to an older generation of scientists and intellectuals. In his book series Vision + Value, Kepes included essays by Buckminster Fuller, Jacob Bronowski, Conrad Waddington, Rudolph Arnheim, and an array of other "scientific humanists" who regularly gathered at Malina's home in Paris. What Malina found less agreeable in Kepes's publications was the artist's predisposition toward a mysticism centered around unity, rhythm, and visual language. In six lavishly illustrated volumes that appeared in 1965 and 1966, Kepes juxtaposed images created by artists with those generated by experimental scientists. While images produced by particle accelerators or telescopes inspired Malina, he never claimed them as being art in their own right. By the mid-1970s, Malina confided that he found "texts by Kepes as bad as those by Fuller . . . these fellows seem to be successful as high-pressure salesmen" with their promotion of "unsupported assertions and platitudes."[43]

Assertions aside, Kepes had indeed been working for years to sell administrators at MIT on the value of his proposed center. In 1965, after submitting a proposal for it to MIT's administration, Kepes published his idea in the journal *Daedalus*. His essay described a "closely knit work community" of artists and designers who would be based in an "academic institution with a strong scientific tradition" such as MIT.[44] Just as paleontologists envisioned human evolution advancing via interbreeding, Kepes proposed that "cultural evolution" would happen through "interthinking" between artists, engineers, and scientists. These collaborations would, Kepes argued, produce a "climate more conducive to the development of new ideas" than artists might achieve by working alone.

Some engineers questioned Kepes's goals. Leo L. Beranek, a former MIT professor of communications engineering, asked whether "scientists and artists [should] be rubbed together" in the first place. The tinder needed to spark new flames should not come from "mature scientists and artists" in some university center but by the "stimulation of young and imaginative students" in the classroom. Undergraduate education was what would eventually produce the hybridized professionals "with a high level of creative achievement in both fields" Kepes wanted.[45] Meanwhile, Cyril S. Smith, a metallurgy professor at MIT with a long interest in the fine arts, supported Kepes and CAVS but because "closer contact with artists" might lead to new research opportunities for scientists and engineers.[46] Making new art was secondary in Smith's assessment.

In the summer of 1965, having received feedback from his colleagues, Kepes—now nearing sixty—wrote MIT's president, Julius A. Stratton from his summer residence in Wellfleet, Massachusetts. Kepes assured Stratton that most scientists and engineers would welcome an organization that would transcend the “modern specialization [that] so often separates artist and scientist.” And, yes, a closer study of the visual realm could reveal the “common ground” between the two communities because all researchers at MIT sought “patterns of order that have coherence and meaning for the eye and the mind.” Much more pragmatic in Kepes’s appeal to Stratton were questions about that currency of supreme value to all academic administrators: campus space. MIT’s president assured Kepes that he remained “deeply and sincerely committed” to “the plans we have been dreaming about for so long” and encouraged him to press forward.[47] (The issue of campus space went unremarked on.)

Kepes and Stratton could dream all they wanted but starting CAVS would take considerable financial outlay. In 1967, MIT proposed an ambitious plan to the Ford Foundation (of which Stratton had since become the head). It asked for $12 million dollars to create a new center that would bring about a “condition of parity for the arts” at MIT. As had been the case a decade earlier, the central question was what kind of education engineering and science students should receive. Once again, the rhetorical ammunition C. P. Snow had provided years ago proved useful. The proposal argued the “ultimate problem defined and popularized by *The Two Cultures*” still remained “unattended” as MIT had not yet managed to attract and educate a “new kind of student . . . trained both in science and the humanities.”[48]

Although the Ford Foundation didn’t fund the proposal, other pitches struck their mark.[49] As a result, in July 1967, MIT’s public relations office announced the formal creation of CAVS, highlighting Kepes’s intent to “develop ‘idioms of collaboration’” between artists, engineers, and scientists.[50] The news prompted a feature article in *Art in America* claiming that new efforts along the Charles River were closing the “science-humanities” gap and creating “a new kind of Renaissance man—the visual designer of tomorrow.” Besides CAVS, there was Harvard’s Carpenter Center. Located in the only American building designed by Le Corbusier, it sought to “eradicate visual illiteracy” by fostering “environments where scientists and technologists and artists collaborate.” Optimistic in tone, the essay concluded with sculptor Richard Filipowski, another Bauhaus alum, proclaiming “Art will always win. But it can’t be built without science.”[51]

Hopes for a felicitous marriage between art and science were symbolized in March 1968 when MIT jointly dedicated the Center for Advanced Visual Studies and the school’s newly created Center for Theoretical Physics. To mark the occasion, Kepes organized the three-day “Symposium on Art and Science” to be held in Kresge Auditorium, a swooping building on MIT’s campus that Eero Saarinen had designed a decade earlier. Kepes’s program included Klüver and Rauschenberg along with physicists Hans Bethe and Robert Wilson (who also sculpted) and designers Charles Eames and Buckminster Fuller. *Artforum* dispatched Grace Marmor Spruch, a condensed matter physicist with a doctorate from New York University to report on the event.[52]

Spruch framed her piece literally as an upstairs-downstairs story. The symposium’s concurrent sessions had the scientists presenting talks on “nuclear matter and field-current identities” in the main auditorium, while discussions about art and technology’s fusion were relegated to “Little Kresge,” a smaller auditorium located in the basement. There was considerable irony here. Just three years earlier, when signing the National Endowment for the Arts into existence, President Lyndon B. Johnson had remarked that the “scientists always seem to get the penthouse, while the arts and humanities are always down in the basement.”[53] Kepes’s own welcoming address was shot through with references to bifurcated cultural identities (“scientists are not unfeeling computers . . . [neither] are artists unthinking bundles of instinct”) and other dualities that had, by now, become common points of reference.[54]

Not all the attendees accepted Kepes’s parsing. After lunch, Jerome Lettvin, a cognitive scientist who had recently debated Timothy Leary on the dangers of LSD in the very same building, took the stage. Rolling up his sleeves, the impressively sized Lettvin announced, “We’ve been handed a Snow job.” He then went on to argue that mutually generative relationships had always existed between art and science. In response, Billy Klüver described how E.A.T. emerged out of the spirit of *9 Evenings*. By not focusing on aesthetics or artistic products, chance and randomness were encouraged as part of a larger creative process between artists and engineers. Likewise, Ivan Sutherland, an MIT-trained electrical engineer, described how computer algorithms could create art that varied with the observer’s participation. Lettvin loudly rejected “this machine rococo, this accidental art,” which “one wouldn’t want—to say the least—in one’s living room.” Perhaps artist-technologist collaborations were, as Lettvin suggested, just like the madman in Cervantes’s *Don Quixote* who seizes a dog, affixes a tube to its backside, and then inflates it—yes, it’s difficult to accomplish but to what end? As Klüver objected that Lettvin had missed the point, filmmaker Stan VanDerBeek retorted, “Who says art has to be in the living room?”[55]

When the symposium drew to an end, Spruch and other guests strolled across MIT’s campus to receptions sponsored by the two new centers. At CAVS, bare white walls and temporary partitions concealed "flashing lights, filters, projectors, brass and steel constructions, wires, magnets, motors," while a stairway took guests to a lower level "reminiscent of accelerator rooms in physics laboratories." Meanwhile, the physics center hosted a posh gathering in MIT's famous Infinite Corridor. Spruch likened the space to a "plush art gallery" with paintings, photographs, and a wire sculpture hanging from the ceiling. "This place looks like a visual arts center," one visitor murmured. All of this dissonance led *Artforum* to label the MIT event as one more contribution to the growing "art and science muddle."[56]

Creating a community of socially engaged artists who would interact with engineers and scientists in Cambridge was central to Kepes's vision for CAVS. Among the small group of men Kepes recruited was Jack Burnham. He arrived at MIT in the fall of 1968 enthusiastic about the opportunity. By the time Burnham's residency had ended, however, his opinions about Kepes, CAVS's mission, and the entire art-and-technology movement had shifted to wariness if not outright pessimism.

Born in 1931 in New York City, Burnham joined the military when he turned eighteen and soon found himself working overseas as a draftsman for the US Army Corps of Engineers. After leaving the service, he earned an associate's degree in engineering from a technical school in Boston before studying fine arts at Yale. As a young artist, Burnham was particularly inspired by the Russian constructivist sculptor Naum Gabo. While working toward his Yale degree, Burnham started to fabricate sculptural works using programmed light sources, fiber optics, and electroluminescent tape. In the 1960s, Burnham also experimented with adding sound and music into some of his works, creating responsive multimedia environments.[57]

Burnham was in the midst of making the transition from artist to art writer when he joined CAVS. His main objective, as he described in application materials, was "applying systems theory to contemporary art" or, as the title of an influential article by him in *Artforum* stated it, advancing a "System Esthetics."[58] His first book, called *Beyond Modern Sculpture*, appeared the year he started at CAVS. In his writings, Burnham explained how he wanted to explore sculpture making as it was historically "overtaken by the dynamics of technological change."[59] Both publications were wide-ranging in scope, with Burnham drawing from an impressive eclecticism of ideas. In just a few pages, one could find references to Thomas Kuhn's *Structure of Scientific Revolutions*, systems biologist Ludwig von Bertalanffy, John Kenneth Galbraith's reflections on "esthetic decision-making," and research briefs from RAND, the defense think tank in Santa Monica where apocalyptic futurism mingled with avant-garde modernism.[60]

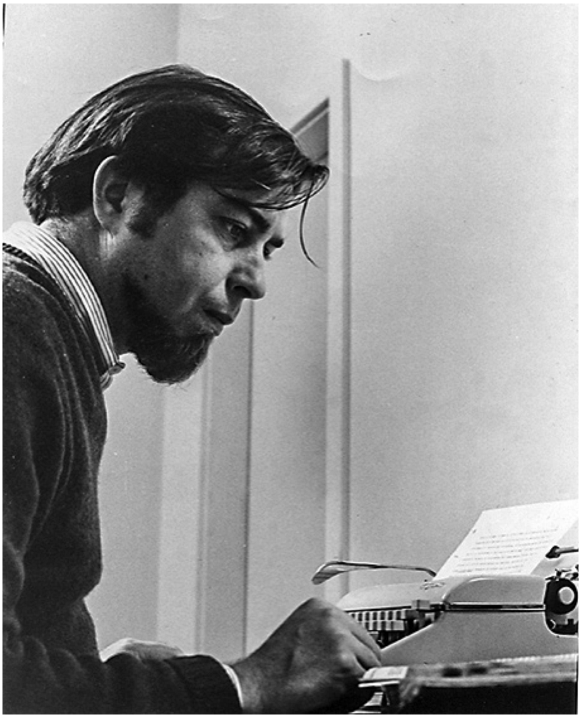

Figure 6.3 Jack Burnham at work, ca. 1969, while he was a fellow at MIT's Center for Advanced Visual Studies. Image courtesy the MIT Program in Art, Culture and Technology.

MIT was a logical place for Burnham to do a fellowship. During the Cold War, the school had become an obligatory passage point for engineers who went to work on large-scale projects intimately tied to national security and the space race. For all practical purposes, cybernetics, with its focus on communication between people and machines, was invented at MIT in the 1940s. After the war, the institute supported pioneering research between scientists and engineers on real-time computing systems that provided the basis for, among other things, a continent-spanning air defense network. By the time CAVS was under way, Lincoln Laboratory and the Instrumentation Laboratory (run by Malina's colleague Charles Stark Draper), where engineers developed innovative missile guidance systems, each employed thousands of people. Their combined funding was more than half of MIT's total annual budget, a factor which later proved a volatile catalyst for campus protests.[61]

Burnham, well acquainted with the military origins of systems engineering, was committed to exploring the larger implications of how this methodology could be applied to understanding art. Burnham had come to see the art world, and society in general, “in transition from an *object-oriented* to a *systems-oriented culture*.” Creative change, he said (using language redolent of E.AT.’s focus on “process not product”) came “not from *things*, but from the way *things are done*.” As a result, the artist was becoming less a maker of stuff than a “maker of esthetic decisions.”[62] Burnham noted that the artist didn’t have to become an engineer but, when working with sophisticated technology, “it would be advisable for him to think like an engineer.”[63] Burnham’s ideas about the artist’s changing professional identity anticipated pronouncements about the factories of the future where “knowledge workers” didn’t so much as make tangible goods but instead managed immaterial flows of data. In the future—whether art or industry—the circulation of relevant information would be key.

Burnham’s writings on “art-as-systems” have since become required reading for modern art history courses. His depiction of the art world itself as a “disparate, sprawling, yet rule-bound system” while simultaneously anticipating aesthetic movements such as minimalism and conceptual art, appears prescient today.[64] The initial reception was mixed, however. Anthony Hill, on reading *Beyond Modern Sculpture*, described it to Malina as a “highbrow ‘coffee-table’ art book . . . nothing of real importance” and paid it perhaps that most damning of judgements: “probably a Ph.D. thesis.”[65] Darby Bannard, an American abstract painter, likewise blasted Burnham’s “execrable verbal smog,” charging the author with mistaking newness for virtue.[66] (Not all reviews were negative. The leading journal for the history of technology dubbed *Beyond Modern Sculpture* a “brilliantly written book” that predicted how art would occupy an “organically vital role in the society of the future.”)[67]

Unlike some art writers, Burnham made an earnest effort to understand the cutting-edge technologies he wrote about. Taking advantage of his MIT residency, Burnham established connections with people like Marvin Minsky, one of the foremost researchers in artificial intelligence, and Joseph C. R. Licklider, a psychologist at MIT studying human-computer interactions. To learn more about real-time interactivity with computers, Burnham started visiting technologists at Lincoln Laboratory. One of these researchers, Jack Nolan, headed Lincoln Lab’s computer systems group and was also a skilled abstract painter. He was preparing an opposite move to Burnham’s, leaving the lab to become the new president of the Massachusetts College of Art. Nolan and other Lincoln staff taught Burnham how to do basic computer programming. A photograph taken in 1969 shows him typing away at a monitor connected to an MIT mainframe. While Lincoln Lab researchers took it as a fait accompli that computers would become essential tools for artists, Burnham was more circumspect. What intrigued him most in these experiments was the process as he "conceptualized an entirely abstract model" and then watched how a "dialogue *evolves*" between the computer and the programmer.[68]

While at CAVS, Burnham continued his reflections on the symbiosis between people and computers. In a provocative *Artforum* essay, he likened artists to "programs and subroutines" who functioned within a larger "metaprogram" of art trends, galleries, and the art business itself.[69] Artists "produce data by making art," which art critics and museum curators attempt to process and make sense of. "History," Burnham quipped, riffing on debates between information theorists like Norbert Wiener and Claude Shannon, "is uncertainty about art minimized." Burnham extended the metaphor to explain how, just as programmers worked in real time within a particular software environment, many artists were increasingly focused on creating responsive environments. He pointed to Hans Haacke's *Condensation Cube*—a hermetically sealed, clear Plexiglas box with a tiny amount of water inside. Conceptually simple, Burnham interpreted it as art in the form of a real-time system that actively but unpredictably changed in response to ambient humidity, light, and temperature.

More complex in execution were what Burnham termed "programmed art environments," created as artists connected electronic computers to light and sound systems. For instance, in late 1968, Pulsa, a small collective of artists and engineers based at Yale University, augmented the pond at Boston's Public Garden with scores of underwater strobe lights and speakers. Triggered by changes in the ambient conditions, the result was a "successful blend of electronics and nature in an urban environment," dazzling yet "completely unostentatious."[70] Pulsa's experiment—their term—as well as its aesthetics impressed Burnham. But running such experiments, as Billy Klüver knew well, demanded considerable financial resources, which in this case meant contributions from local universities and businesses. Consequently, Burnham saw groups like Pulsa and E.A.T. as artistic endeavors ultimately "brought up (or down) to the level of corporate research."[71]

Critics' enthusiasm for Pulsa's collectivist approach to art making stands in contrast to Kepes's own failure to mobilize the resources to make the monumental works of art he envisioned. Highest among his priorities was building a "programmed, luminous structure floating in Boston Harbor" made of mirrored buoys and a mile-long wall of light. By "animating water and sky," Kepes wanted this civic art to "welcome visitors" while offering a "truly twentieth century reminder that, in spite of all our manmade wonders, nature, the sea and sky, are still with us."[72]

After he left CAVS, Burnham painted a different picture, recalling interminable staff meetings to discuss Kepes's "vague dreams." "What was the civic purpose of the light monument?," he asked. "*No one really knew.*" Nor had Kepes done any of the necessary research into the cost of laying underwater electrical conduits or ensuring the project didn't interfere with flight patterns at nearby Logan Airport. Burnham's disillusioned critiques suggested the limits of artists working with advanced technological systems in the absence of professional engineers.[73] As the 1960s ended, Burnham came to believe that a systems approach could help explain modern art, but the real, undiscovered roots lay "far deeper than any of the advanced technologies in use today."[74]

ALL WATCHING MACHINES OF GRACEFUL LOVELINESS

In April 1967, a few months before the eclectic chaos of the Summer of Love, Richard Brautigan began to pass around copies of his hand-folded chapbook to strangers and friends in San Francisco. Among the thirty-two poems in the slight volume was one that provided the collection its title: *All Watched Over by Machines of Loving Grace*. A year later, a Bay Area activist group gave away 40,000 more copies—its popularity had been boosted in part by the 1967 appearance of Brautigan's counterculture classic, *Trout Fishing in America*. In his poem, Brautigan envisioned a "cybernetic meadow" where "mammals and computers" lived in "programm[ed] harmony." He wrote:

> I like to think
>   (it has to be!)
> of a cybernetic ecology
> where we are free of our labors
> and joined back to nature,
> returned to our mammal
> brothers and sisters,
> and all watched over
> by machines of loving grace.[75]

Interpreters of Brautigan's poem have framed it as both a techno-utopian longing and a writer's scorn for Cold War technological systems. However, what's most striking is that a Beat Generation writer would have written about cybernetics in the first place. Brautigan's poem suggests the distance that esoteric concept had traveled as it migrated from military research and academic conferences into popular culture. Throughout the mid-1960s alone, “cybernetics” and its cognates appeared in hundreds of newspaper and magazine articles. Just as 1968 represented a distinct peak in the art-and-technology movement, it was likewise for cybernetics.[76] In the final part of this chapter, we’ll look at how these two trends converged in a pair of international art exhibitions.

For three months starting in August 1968, visitors to the Institute for Contemporary Arts, located just off London’s Trafalgar Square, had the opportunity to see one of the most ambitious art-and-technology exhibitions of the 1960s. It also provided an introductory primer to computers and cybernetics. Jasia Reichardt, a thirty-five-year-old curator at the ICA, organized the show. Born in Poland, Reichardt relocated to London after World War II where her aunt and uncle, Stefan and Franciszka Themerson, operated Gaberbocchus Press. The Themersons published visually daring (“not best-sellers but best-lookers”) avant-garde books while also operating the Gaberbocchus Common Room. This was a community space for people to meet, play chess, and discuss art and science.[77] Invitations to the Common Room’s gatherings (C. P. Snow, naturally, was among those included) claimed not to “identify science with gadgetry, nor art with a kind of romantic irresponsibility. We would rather prefer to see both sides as investigators and explorers of the universe.”[78]

Reichardt displayed the same holistic perspective when she started planning what became “Cybernetic Serendipity: The Computer and the Arts.” Like Frank Malina, who she later came to know, Reichardt believed it possible to scientifically assess the effectiveness of art. Another important stimulus for the exhibit came from a conversation with Max Bense, a German literary critic and philosopher who had influenced the New Tendencies group. At an exhibition of concrete poetry Reichardt organized at the ICA in 1965, Bense suggested she “look into computers,” as the first computer-generated artworks were starting to appear in galleries and magazines.

Raising funds for the show took the better part of two years, during which Reichardt made contact with E.A.T. members and toured IBM, Bell Labs, and other hubs of computing activity in the United States.[79] By August 1968, when “Cybernetic Serendipity” opened, Reichardt had raised £20,000 for the show. She also persuaded Britain’s Minister for Technology to preside over the opening (Max Bense spoke at it, closing that particular feedback loop). That it was organized by a woman, when technological art, let alone computing in general, was male-dominated, marks an accomplishment of a different stripe.

IBM's contributions helped Reichardt achieve one of the show's main goals: exposing the visitors—some 60,000 people saw "Cybernetic Serendipity" during its two-and-a-half-month run—to computers. Big Blue provided display models illustrating basic principles like programming, data processing via punch card, and real-time information handling. This was likely the first time that many visitors had seen, let alone interacted with computers, so "Cybernetic Serendipity" assumed a pedagogical function as well. Lengthy statements in the show's catalog from Norbert Wiener and other writers explained technical concepts of computing while, in the gallery, people could also read about the history of cybernetics.

Reichardt intended her show's title to convey the idea that computers afforded artists unforeseen opportunities. As she wrote in 1968, the show dealt with "possibilities rather than achievements."[80] It was "not an art exhibition as such, nor a technological fun fair, nor a programmatic manifesto." This ambiguity caused some dissonance for art critics who were unsure how to situate it vis-à-vis traditional exhibits. Instead, she wanted to demonstrate the often unseen linkages between computers, cybernetics, and creativity while offering examples of "machine-aided creative processes."[81] One strategy she used was not specifying whether the works on display had been made by engineers or artists, stating that this information "might make us see them differently." (Only forty-three of the show's 130 contributors, in fact, self-identified as artists.)

Beyond the computer displays, visitors encountered an array of computer-generated art and music, with many works taking their cue from the exhibition's moniker by incorporating varying degrees of randomness. One group from Cambridge University deployed a computer program that produced haikus while another researcher's "high-entropy essays" mimicked papers written by undergraduate physics students. But what captured the attention of visitors and art critics most were the actual three-dimensional cybernetic and computerized artworks Reichardt had assembled. Many of these were by artists one expected to find in a show devoted to electro-kinetic art such as Nicolas Schöffer and Jean Tinguely. Malina's contribution was *Entrechats II*, a small audio-kinetic piece he made in 1966. It used a rotating, light-reflecting system to project images onto a translucent screen, their motion influenced by the intensity of ambient sound.

Reichardt also showcased work by several new artists. Critics and journalists especially responded to a work by Wen-Ying Tsai. Born in Xiamen, China in 1928, Tsai moved to Shanghai where he took courses in chemical engineering. In 1950, he emigrated from Hong Kong to the United States and studied art and mechanical

Figure 6.4 A view of the 1968 "Cybernetic Serendipity" exhibition, curated by Jasia Reichardt, at London's Institute of Contemporary Arts. In the foreground is Edward Ihnatowicz's *Sound Activated Mobile* (1968) while Nam June Paik's *Robot K-456* (1964) is in the center background. Image courtesy Jasia Reichardt, © Cybernetic Serendipity.

engineering at the University of Michigan. Degree in hand, Tsai worked in New York City as a consulting engineer for several high-profile architecture firms while developing his skills as an artist. The Museum of Modern Art included his painting *Random Field* in its 1964 show "The Responsive Eye" and it was around the same time Tsai started to experiment with three-dimensional kinetic constructions. After becoming an American citizen, he gave up his engineering career to be a full-time artist.[82]

1968 was a breakout year for Tsai. In May, he displayed eight pieces, collectively called *Cybernetic Sculpture*, for a one-person show at the Howard Wise Gallery in New York. (Yes, the artist did sometimes call his work "Tsai-bernetics.") The eight works, one of which Tsai also submitted for Reichardt's show, were presented in Wise's dimly lit gallery with a blue-tinted strobe light trained on each. Tsai's pieces consisted of long stainless-steel rods of different shapes and sizes, sometimes with a polished metal plate on the top, set in cement. Tsai engineered them so they vibrated at twenty or thirty times per second. What happened next depended on the viewer, who, through various actions, could control the rate of the strobes. When the strobe flashes were synchronized with the rods' vibration, they appeared stationary. But the lights could also be altered by speaking loudly, clapping hands, or simply the viewer's proximity.

As a result of these interventions, Tsai's pieces appeared "like the tentacles of sea anemones under water" or "the stem of a plant, set atremble and aquiver electronically." Other critics noted that Tsai's artworks extended what Naum Gabo had explored decades earlier in pieces like his *Kinetic Construction (Standing Wave)*. Tsai, however, had added a cybernetic twist, in which mechanical motion combined with viewers' behavior.[83] Not all critics were favorably disposed toward this sort of interactivity. One critic declared that such demands for audience participation created "a distasteful pseudo-scientific laboratory set forth in the name of art," which influenced and overdetermined viewers' conduct.[84] Nonetheless, soon after the "Cybernetic Serendipity" show, Gyorgy Kepes invited Tsai to join CAVS as a visiting fellow. He arrived at MIT buoyed by growing attention from art critics and a prize his work had recently won in an E.A.T.-affiliated international exhibition in which new cybernetic artworks were prominently featured.

The plans for this show, called "The Machine as Seen at the End of the Mechanical Age," started in 1965 when the Museum of Modern Art's director encouraged Pontus Hultén to assemble an exhibit on kinetic art. The Swedish curator decided to expand on this suggestion by referencing another show MoMA had hosted decades earlier. In 1934, the curators of "Machine Art" had displayed scores of factory-made items as "beautiful objects" in their own right.[85] Leap forward thirty years and Hultén, informed by conversations with Billy Klüver, believed that technology itself was in transition. "The mechanical machine," he wrote for the exhibition's catalog, "is losing its dominating position among the tools of mankind" as new "electronic and chemical devices" replaced it.[86] Hultén wanted to reflect on the struggle between people and traditional machines for power, even as new devices based on information and systems were assuming growing importance for economists, engineers, and artists.

Hultén eventually selected some 200 objects, including drawings by Leonardo da Vinci, eighteenth-century automatons, exotic automobiles, and an assortment of

Figure 6.5 Wen-Ying Tsai in his studio at MIT's Center for Advanced Visual Studies. Image courtesy the MIT Program in Art, Culture and Technology.

international artworks that reflected a wide swath of twentieth-century art trends. Hultén didn't want the show to just be a historical retrospective so he and Klüver decided to also include new works that highlighted artists' "possible openness toward the future" where artists and engineers regularly worked together.

In November 1967, E.A.T. announced a competition for engineers and artists. Three prizes would be given to the "best contribution by an engineer to a work of art produced in collaboration with an artist." The selection jury would be scientists and engineers who were "not necessarily familiar with contemporary art." They instead were instructed to "disregard esthetic preferences" and instead evaluate entries for their "inventive use of new technology."[87] For engineers who had already worked with artists, as well as those new to the idea, the competition offered a chance to have their creativity recognized instead of being "invisible technicians." In addition to monetary awards, Hultén said he would include the best works in his MoMA show. In all, artist-engineer teams from nine countries submitted some 147 entries, an accomplishment that also helped boost the membership of engineers in E.A.T.[88] In November 1968, Klüver, along with Hultén, Theodore Kheel (his labor organization provided some prize money), Robert Rauschenberg, and representatives from labor groups, announced the winning collaborations. Each of the works, by responding to people and the environment, reflected in varying ways Jack Burnham's concepts of "real-time systems."

One of the runner-up prizes ($1,000) went to the team of Frank T. Turner and Wen-Ying Tsai for a cybernetic sculpture. Turner, an electrical engineer for Western Union, helped Tsai perfect a system that allowed the sculpture to sense and respond to sounds in real time. One reporter who attended the unveiling at MoMA noted how Tsai's piece made the audience laugh as the machine's oscillations "gave the impression of burlesque gyrations." The other second-place prize went to the husband-wife team of engineer Niels O. Young and artist Lucy J. Young for their simple, yet elegant piece *Fakir in 3/4 Time*. The Youngs conceived the piece as a choreographed mechanical fountain of sorts. At its heart was a piece of textile rapidly spun, lariat-fashion, by an electric motor. As it rapidly circulated, it formed an ever-changing loop that the Youngs could vary in height from four to forty feet. With a title suggesting an Indian ascetic, *Fakir* "soared like a Brancusi bird, twisted into a Möbius band, and wheeled into an ellipse."[89]

Figure 6.6 *Fakir in 3/4 Time*, a mechanical "fountain" made by Lucy and Niels Young, 1968. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

Engineers Harris Hyman and Ralph Martel, working with French-born artist Jean Dupuy, took top honors (and $3,000) for their *Heart Beats Dust: Cone Pyramid*. This consisted of a black rectangular box with a glass viewing port placed at eye level. A bright light in the box's "roof" projected a sharp-edged cone of illumination downward. Inside the box, they placed some Lithol Rubine, a fine-grained, brilliant red synthetic pigment. Its low density allowed it to remain suspended in air for long periods of time. This dust rested on top of a rubber membrane, underneath of which the engineers placed an audio speaker. A tape loop of a human heartbeat, played through the speaker, made the red dust bounce upward in response to the sound, creating vibrant, eerie tendrils reminiscent of blood. Unfortunately, surviving photographs hardly do the piece justice (especially those in black and white). Like many works coming out of the art-and-technology movement, the effects of *Heart Beats Dust* were often ephemeral or, at the very least, possessed a pronounced "you-have-to-experience-it-yourself" quality.

The three winners, along with six other works by engineer-artist teams, were displayed at MoMA for the show's gala premiere in November 1968. As they had for *9 Evenings*, Klüver and his engineering colleagues collected data (which they published) as to what percentage of works displayed functioned properly and how this might be improved.[90] To complement the popular exhibition, Hultén commissioned a Swedish manufacturer of beer cans to create the catalog's cover from thin sheet steel, embossed with a full-color illustration of MoMA's facade. Klüver, meanwhile, contributed an essay about art and technology. The remaining contest entries were displayed concurrently in a smaller show, titled "Some New Beginnings," at the Brooklyn Museum of Art. Overall, these exhibitions brought renewed attention to E.A.T. One critic praised Hultén's effort ("brilliantly organized") for showcasing aesthetically exciting works with a "sense of wonder" while also providing a "historical frame of reference too often missing from recent art-and-technology exhibitions."[91]

Hultén invited Klüver to be part of an evening lecture series that accompanied the "Machine" show. In December 1968, more than eight years since he had conspired with Jean Tinguely to build a suicidal machine that (literally) made a big stink in the museum's courtyard, Klüver spoke about "The Artist and Industry." His views about effecting collaborations between engineers and artists had evolved notably by that time. In 1960, he pointed out, economist Kenneth Galbraith had encouraged American businesses to purchase art, an investment to help industry "come to terms with the artist."[92] This strategy was no longer as relevant, Klüver argued. Now, artists acted much more like experimental scientists, regardless of whether they used a "pencil or a laser beam." A main catalyst for this professional transformation was artists' closer collaboration with industry that E.A.T. had provoked. "Only industry," he said, "can give the artist what he wants."[93]

Moreover, industry and artists alike were increasingly becoming "function-oriented rather than product-oriented." Industry, therefore, needed to redesign its relationship with artists and accept the view—promoted, of course, by E.A.T. and other collaboration-oriented groups—that what really mattered was artists' experimentation with new technologies. "No one asks a scientist why he wants to use a laser beam," Klüver noted, and artists should be free to do likewise. All of this, Klüver noted, making a rare reference to contemporary politics, might seem an indulgence in the midst of the Vietnam War, the civil rights movement, and "the situation in the underdeveloped countries." But, by investing in "process and possibility" over "product and posterity," industry executives could help artists "function as a catalyst to bring technology to the individual."

In the late 1960s, dozens of companies, perhaps hearing injunctions like Klüver's, started to help artists and the engineers who wanted to explore these new possibilities. As the chaos and crisis that marked 1968 persisted, art-and-technology advocates encountered new challenges. One was practical. Just as technologists had learned to manage endeavors like space missions and big research programs, a similar need emerged as some art-and-technology collaborations made quantum leaps in terms of their scale, visibility, and corporate investment. But people like Klüver and Kepes faced a more existential dilemma. Industry, museums, and universities were devoting more energy and resources—people as well as capital—to advancing the merger of art, technology, and science. But could these efforts maintain momentum in the face of ever more vocal critics of modern technology, the corporations that built it, and the military that used it? Did collaboration necessarily mean complicity and compromise and when, if ever, could it also offer critiques?

7

PARALLEL PROCESSING

There is no profit in art beyond its experience.[1]

Barbara Rose, 1970

By 1969, Stephen Nowlin had tuned in. He had definitely dropped out. But what really turned him on wasn't the readily available psychedelics to be had as he traveled around coastal California. True, many people his age had, as one writer from the Golden State observed, fled the rational world of science and technology "as if from a place inhabited by plague." However, it was these very topics which so fascinated the once and future art student.[2]

Having growing up amid the prosperity that the Cold War aerospace industry had brought to Southern California, in 1966 Nowlin moved to Oakland for studies at the California College of Arts and Crafts. He attended a few Happenings in the Bay Area, experimented with personal video equipment, and made music with electronic synthesizers.[3] But none of his art school classes reflected these trends. However, E.A.T.'s ripples had begun to resonate within the West Coast art scene. So, in late 1968, Nowlin literally left his homework on the drawing board and moved back to Southern California.

While working for an architectural firm in Pasadena, Nowlin started hearing about a new art initiative taking shape at the California Institute of Technology. Like MIT's efforts in the visual arts, the art program at Caltech—a school smaller in terms of students but MIT's equal in terms of prestige, star researchers, and close ties to the defense establishment—started as a “humanizing move” that could help the school attract and retain students.[4] Nowlin soon found employment as a draftsman at an astronomy lab at Caltech and began spending time with people associated with the art initiative.

He quickly realized that many Caltech faculty imagined “The Artist” as some sort of throwback to 1940s-era bohemian stereotypes (picture a solitary artist with easel and beret) and thought of art making as a type of hedonistic therapy, not an actual profession. Years later, Nowlin recalled a campus encounter with physicist Richard Feynman. While Nowlin was on his way to Caltech’s main computing center, where he was learning to write code for making art, the Nobel Prize-winning scientist was headed, sketchbook in hand, to a live-model drawing class. (One can imagine Frank Malina dismissing Feynman’s Degas-like sketches as just like the “nudes, flowers, landscapes, and dead fish” he had rebelled against years earlier.) Eventually, Nowlin returned to school, this time at the California Institute of the Arts where avant-garde experimentation was more encouraged. After earning a BFA and MFA, Nowlin accepted a faculty position at the Art Center College of Design, just a few miles from the arroyo where Malina had done his first rocket experiments decades earlier.

In addition to deepening his appreciation of science and technology as a “more complex kind of beauty,” Nowlin’s experiences with Caltech’s arts program alerted him to more powerful currents surging westward from New York City as well as new forces generated within Southern California. Starting around 1967, engineers, artists, corporate managers, and museum curators initiated two major art-and-technology initiatives rooted in the Los Angeles area. The sheer scale and cost of them ensured an abundance of media coverage. A half century later, these two projects radiate strong signals from the archives that attract a historian’s attention. As with *9 Evenings*, this documentation offers a chance to more closely appraise the involvement of engineers along with their artist partners.

Reflecting Billy Klüver’s evolving ideas about the relationship between artists and industry, in 1968 Experiments in Art and Technology formed a partnership with the American soft drink maker, PepsiCo. The company hired E.AT. to design its pavilion in Osaka, Japan for Expo ’70, the first world’s fair held in Asia. Although managed out of E.A.T.’s New York headquarters, a significant amount of the research and development for the Pepsi Pavilion was conducted in and around Los Angeles.

A parallel project was launched by Maurice Tuchman, a young curator at the Los Angeles County Museum of Art (LACMA). LACMA’s effort—appropriately called the

Art and Technology Program—catalyzed dozens of collaborations between artists, corporations, and the engineers who worked for them. Some of the artworks they produced would be shown at Expo '70, as part of the United States' official program, and then, a year later, at a major exhibition Tuchman organized at LACMA.

Even though the E.A.T. and LACMA projects were conceived, funded, and managed as separate entities, they happened concurrently, like a computer executing a series of related calculations at the same time. Not surprisingly, considerable cross-pollination occurred between the people associated with the pavilion and the artists and engineers Tuchman brought together. And, of course, all of this activity was taking place as arbiters of culture were striving to position Los Angeles as a new center of contemporary art that might rival the New York establishment.

LACMA's Art and Technology Program and the Pepsi Pavilion project stand as high points of the art-and-technology movement of the long 1960s. Both efforts happened in the midst of increased scrutiny of the art world's connections to corporate sponsorship, debates about artists' ownership of their work, and criticism about the lack of diversity among the artists included in major exhibitions. As the Vietnam War intensified and American economy began to falter, a backlash against technology polarized these reactions further as the art-and-technology movement surged markedly and then just as quickly began to ebb. Even though an increasingly capable community of artists and technologists were securing new institutional footholds, questions arose as to whether large-scale, formal collaborations could still electrify critics and audiences.

OF KANDY KOLORS AND A COWBOY CURATOR

For much of the 1960s, calling Los Angeles "artistically barren" was as easy as finding fresh oranges there. Ambitious artists were obliged to travel to New York while the world outside Manhattan was understood as nothing more than overlooked regions at best, centers of talentless provincialism at worst. But, just as any history of the art-and-technology movement that ignores the role of engineers is lacking, so too any history of modern art that focuses only on New York is incomplete.[5]

At first, the "priestly caste of critics and curators" greeted the emergence of a thriving new community of galleries and studios in Los Angeles "with all the enthusiasm and bonhomie of the sixteenth-century church confronted with a heliocentric universe."[6] One critic, who judged the city a "vital pathology," categorized art made in Los Angeles as either "sweaty" or "sterile"—a judgment referring to the lurid tableaus of Edward Kienholz and the "desperate prettiness" exemplified by so-called Light and Space artists.[7]

Well before Stephen Nowlin moved north for art school, his hometown region had started cultivating a thriving arts scene. Led by curator Walter Hopps, a bespectacled, smartly dressed autodidact in art history (his formal schooling was in biochemistry), the Ferus Gallery helped spark the growth of a new creative community based in West Hollywood. Artists, many of them recent transplants to Los Angeles, showed their work at Ferus and the other galleries that began clustering along La Cienega Boulevard. The atmosphere was avowedly masculine, the group's members expressing themselves through surfing, hot rods, and philandering, as well as their art.

Ties to UCLA's art department and local art schools where experimentation was encouraged fueled the scene further. Ferus presented Andy Warhol's first solo show in 1962, the same year that Hopps, his peripatetic nature heightened by his intake of amphetamines, curated the first exhibition of pop art in the United States. Held at the Pasadena Art Museum, the "New Painting of Common Objects" show featured artists from both coasts, including Warhol, Roy Lichtenstein, and Ed Ruscha. The next year, Hopps's retrospective of Marcel Duchamp's work in Pasadena further riled the locals (often branded as "rich, retired, and reactionary") but signaled Southern California as an emerging center for modern art.[8]

New arrivals increased the momentum. In March 1965, the Los Angeles County Museum of Art—located about a mile east of La Cienega's gallery scene—formally opened its doors. Although *Time* poked fun at its location ("temple on the tar pits") it promised Angelenos "vastly more substance than was ever to be seen in a DeMille sunset." In a city both prosperous and growing (and yet also riven by extreme racial and economic inequality—the Watts riots broke out in August 1965), LACMA debuted just as the region seemed "uniquely ready to spend money on culture."[9] This transformation had already been noticed by some mainstream magazines, which pronounced Los Angeles as "second only to New York City as an art market."[10] It offered, in other words, a vastly different arts environment compared to what Frank Malina experienced in the 1930s.

The migration of *Artforum* from San Francisco to Los Angeles provided another sign of the seismic shift under way. Located upstairs from the Ferus Gallery, the magazine brought lots (some said too much) attention to that gallery's artists, while extolling a style critics branded as the "Finish Fetish." The term, playing on the supposed superficiality of all things Californian, referenced a popular trend for minimalist artworks meticulously crafted using industrial plastics, resins, and paints. These sculptural works paralleled the "kandy-kolored" shimmer that writer Tom Wolfe found so tantalizing in California's thriving, custom-car culture. It was a provocative style, to be sure. One (New York) critic, livid after viewing an exhibition of so-called Finish Fetish artists, savaged their work as "fancy baubles for the rich."[11]

Art critic Barbara Rose, who had been married to artist Frank Stella in the early 1960s, displayed a more open mind when describing her visit to "our new 'second city.'" Like Don Draper, the existentially troubled advertising executive from television's *Mad Men*, Rose found the "brilliantly sunny, palm-studded, Day-Glo landscape" a welcome alternative to Gotham's "frigid lofts and littered slums." Los Angeles artists achieved a "machine-like precision" with "polished, slippery surfaces" that suggested the "pervasive eroticism" of body builders seen at Venice Beach. Overall, she found the city's galleries thoroughly infused with vibrant popular culture and artworks that promised an "orgiastic future."[12] (One senses that Rose enjoyed her time in Los Angeles.)

Rose's former classmate, Maurice Tuchman, was one of those people who looked at Los Angeles and saw a sleek transistorized future. To hear Ed Kienholz describe his friend was to imagine a superhero: a "Sebring-trimmed, 18-hour-a-day dynamo," a curatorial cowboy who learned to drive by barreling his new Ford Mustang down Los Angeles' freeways, and brought "karate chops of effectiveness" to the city's art scene (all while pining for his sweetheart, a soap opera actress named Blossom Plumb).[13] The reality was only somewhat less epic as Tuchman's career of curator-as-celebrity traced a boom-and-bust pattern familiar in his new hometown.

Tuchman grew up modestly in the Bronx where he imagined becoming a comic-strip artist while aimlessly taking courses at City College of New York. Then he discovered a facsimile copy of the Book of Kells, a ninth-century illuminated manuscript, and the possibilities of art history seized his attention. He took graduate courses at Columbia University with famed critic Meyer Schapiro and counted Clement Greenberg as a mentor. He intended to focus on medieval art but, lacking requisite skills in Latin, turned to modern and contemporary art. A position at the Guggenheim revealed the ways in which a museum could be a mesmerizing "confluence of art and power, scholarship and money." He brought this perspective westward in 1964 when, just twenty-seven years old, he joined LACMA's curatorial staff. Tuchman arrived in Los Angeles "particularly sensitive," he recalled, to the city's "futuristic character . . . especially as it is manifested in advanced technology."[14]

Figure 7.1 Maurice Tuchman, curator of twentieth-century art at the Los Angeles County Museum of Art, 1972. Photo © Museum Associates.

Despite his new address, Tuchman opted to survey New York's abstract expressionists for his first major show. The following year, however, he organized a controversial retrospective of Kienholz's work. Chief catalyst for the uproar was *Back Seat Dodge '38*, a lurid sculptural piece made in 1964 that portrayed an anonymous couple having sex amid beer bottles and other detritus inside a truncated auto body. Censorship attempts by local politicians drew lines of visitors that stretched down Wilshire Boulevard. The publicity secured Tuchman's reputation as an enfant terrible of the museum world. A year later, Kienholz penned his flattering profile of the new "super curator" for the *Los Angeles Times*. At the essay's end, the artist signaled his friend's next move: Tuchman was planning to broker a "historical marriage" that would combine the "talents of the best artists" with "the incredible resources and advanced technology of industry," an endeavor that would "revamp the face of America, starting with California."[15]

CORRALLING MISSY'S CORPORATIONS

The "incredible resources" Kienholz referred to were also quite diverse. First, and what most people knew about, were the companies connected with the city's film and television studios. The Hollywood sign was visible from LACMA, at least on smog free days. Less noticeable but far more economically and demographically important was the aerospace industry. At the peak of the Cold War, aircraft and missile production accounted for a third of the region's manufacturing jobs. Between 1959 and 1967, these companies, supercharged by the Apollo program and the war in Vietnam, saw employment of engineers and related employees soar nearly 200 percent.[16] Just as Billy Klüver saw technologies from Bell Labs as a "palette" he might share with artists, Tuchman viewed Los Angeles, with its vast expanse of corporate wealth and engineers' technical skills, as a deep reservoir he would draw on.

A few Angelenos had already started tapping this well on their own as new materials and processes slowly diffused from factories to artists' studios. Around 1965, for example, Larry Bell learned about a vapor deposition process used to apply ultrathin coatings to aircraft canopies and camera lenses. Bell hired a Los Angeles company to fabricate glass panes to his specifications but eventually acquired his own vacuum chamber and, after reading a textbook on thin-film technology, started to experiment.[17] Bell assembled these coated pieces of glass into artworks that presented viewers with simultaneous and shifting senses of opacity, iridescence, and transparency. Although the light and space movement was sometimes criticized—as late as 1971, one writer still sneered that it was as easy to succeed as an artist in Los Angeles as it was "to be a stringer of beads"—naysayers seemed unwilling (or incapable) of appreciating the technical acumen needed to produce such visually rich works.[18]

Los Angeles' extensive and varied technological ecosystem produced a range of companies and business for artists to connect with. There were, of course, the large and prosperous industrial conglomerates—the sort that Tuchman gravitated to—which employed thousands of engineers, technicians, and other workers. But there were also scores of smaller firms, some of them subcontractors for the larger aerospace companies. For example, Jack Brogan had made furniture in his native Tennessee before moving to Los Angeles in 1958 and opening a specialty fabrication business. Brogan crafted custom-made objects for local companies, including a prototype space station model for a local company that specialized in aircraft engines and environmental systems for NASA's space vehicles.[19] At a LACMA show in 1966, Brogan met artist Robert Irwin who soon hired him to make a series of meticulously crafted acrylic plastic prisms, including a thirty-two-foot-tall, optically clear obelisk, its surface polished to perfection like a telescope's mirror.[20]

In 1971, when Tuchman highlighted the final results from his Art and Technology Program, he was circumspect as to where the idea for merging art and industry first originated. But the curator acknowledged he had been "studying the nature and location of corporate resources in California" for some time.[21] When he visited the 1966 Venice Biennale, the "irrelevance of most of the art to American life" left Tuchman feeling "disturbed."[22] Other factors shaped his thinking as well. For example, in 1965, the Long Beach campus of the California State University system hosted the International Sculpture Symposium. Months before E.A.T. and *9 Evenings* first made national headlines, this innovative show connected artists with local industry.[23] For instance, *Now*, a piece jointly made by sculptor Piotr Kowalski with technicians from North American Aviation, used underwater explosions of dynamite to mold massive sheets of stainless steel into gently curved shapes.

Tuchman and Klüver were not, however, the only people with the foresight to imagine the possibilities that could happen when artists were embedded in industrial settings. In 1966, London-based artists Barbara Steveni and John Latham formed the Artist Placement Group (APG). Robert Adeane, who sat on the board of companies such as Shell, helped Latham and Steveni situate artists within corporate settings. But where Tuchman saw these partnerships in largely instrumental terms, the APG brought a more theoretical and activist-inclined orientation to the table. With the belief that "context is half the work," APG wanted to see artists function as independent actors, even participating in companies' decision making. This idealistic goal—one critic labeled it "conceptual engineering"—prompted one IBM executive to remark, "If you [APG] are doing what I think you are doing, I wouldn't advise my company to have anything to do with you. And if you're not, you're not worth taking into account anyway."[24] The APG's activities, which persisted well into the 1980s, suggest just how much the idea of embedding artists into industrial settings was in the air at the time, and not just in the United States.

A final but critical ingredient helped Tuchman launch his art-and-technology effort: Marilyn B. "Missy" Chandler. The socialite and philanthropist had read Kienholz's laudatory profile of Tuchman in the *Los Angeles Times*, which her husband Otis Chandler published. The next day, the influential arts patron wrote Tuchman at his LACMA office and revealed that she had recently "been approached by an exciting new foundation . . . called Experiments in Art and Technology," which she had learned about through her friend Marian Javits. Chandler also recalled how, at Tuchman's recent show, "American Sculpture of the Sixties," she was "startled and delighted" to hear that artists were "most anxious to work" with "local scientific and electronic companies and engineers."[25] Chandler explained how Javits was helping "to bring industries and the artists together" in New York. Likewise, as E.A.T.'s self-christened "West Coast catalyst," Chandler wanted to gauge possible interest for a "parallel group," especially as she had the ability to "attract the industries in the area" to such an effort.[26]

Four years later, the catalog cover for LACMA's Art and Technology Program featured small portraits of artists and the executives (including Otis Chandler) whose companies had supported them. All were men, and the group was overwhelmingly white. Despite this exclusion, Chandler and her network handily connected Tuchman to executives at companies ranging from Walt Disney Productions to Hughes Aircraft. By the end of 1967, she had helped persuade more than a dozen of them—what Tuchman referred to as "Missy's Corporations"—to join the effort.[27] Tuchman, for his part, came to realize that getting corporate chieftains to donate time and money was one thing. The real work was persuading middle managers to follow through on their bosses' commitments. A "congenial company representative" or "alert sympathetic engineer" proved a "critical factor" as the artists Tuchman invited to join the program started touring corporate facilities.

When he visited Missy Chandler at her estate in San Marino, Tuchman would have driven past nearby Caltech. "It was just so impressive to me," he recalled, "the home of geniuses."[28] One of the intellects Tuchman tapped was physicist Richard

Feynman. As a consultant to the LACMA project, Feynman sometimes accompanied curators on visits to companies interested in collaborating with an artist. While Tuchman was undoubtedly impressed with Feynman, the physicist—whose appreciation of modern art did not always equal his understanding of science—reacted less positively to some of the artists he met. A few, he later complained, "had absolutely no idea about the real world" and saw technologists as "grand magicians who could make anything." Even worse were the "absolute fakes" who made "no sense whatsoever." (James Lee Byars, whose conceptual works flirted with Eastern mysticism, especially annoyed him.) But a few artists, such as Light and Space artist Robert Irwin, expressed ideas that seemed incomprehensible at first but which Feynman eventually found "interesting and wonderful."[29]

For a program designed to exploit the resources of Southern California's corporations and challenge New York's hegemony in the art world, Tuchman recruited quite a few artists from his old hometown. The report he edited when his initiative ended included material on seventy-six artists. Thirty-four of them were from New York, twenty-two were Angelenos, and nearly all were white men. The notable exception was Frederick Eversley, an African-American engineer-turned-artist who made reflective and translucent sculptures from cast resin and other nontraditional materials. Tuchman, however, only engaged with one woman, Channa Davis, and ultimately her project wasn't carried out. Scores of other artists (including a "high proportion" of women) sent Tuchman unsolicited proposals, and some of them toured corporate facilities. However, in the end, all of the artists who exhibited their work for the Art and Technology Program had been directly recruited by Tuchman or his associates.[30]

Tuchman's original plan was based on a two-part art-and-technology exhibition. One would be historical, demonstrating the "extent to which modern art has been concerned with the implications of the technological revolution." This would include works from early twentieth-century artists, such as members of the Bauhaus and Russian constructivists. The other part would focus on contemporary collaborations between artists and industry. "It is expected," he noted, that this alliance "will prove so profitable both to industry and to art that a permanent marriage of the advanced forces" in both areas would occur.[31]

LACMA's trustees, many of them corporate executives themselves, hesitated before formally approving Tuchman's project. Tuchman's progress reports to them predicted at least $140,000 of support from some twenty companies, each contributing $7,000. By April 1968, the museum's leaders had acquiesced. In the end, thirty-eight companies contributed some level of funding as the museum created a variety of categories (from “Patron Sponsor” to “Benefactor”) to encourage wider participation. LACMA itself gave generous support for the Art and Technology Program. Because companies also donated equipment, materials, and engineers’ time, estimates of the final outlay for Tuchman’s effort are difficult to make but it’s not unreasonable to think it cost as much as $3 million in today’s currency.[32]

Tuchman expected some artists to express moral opposition to collaborating “with the temples of Capitalism,” especially “militarily involved industry.” But this issue “never became consequential,” leading Tuchman to publicly compare the “politically conscious artist” of the late 1960s to “Trotsky writing for the Hearst Empire.”[33] What many artists *did* find odd, if not objectionable, was the instrument Tuchman used to bind them to corporate partners. A five-page contract spelled out sponsorship terms, including travel reimbursement and honorarium, the total of which was not to exceed $4,800. More problematic, however, was a clause stipulating that the “principal work of art created” would become the sponsoring company’s property. Companies were asked to sign a similar reciprocal agreement. To be fair, the artists would own “additional” works resulting from the sponsorship and Tuchman encouraged them to “plan their work in series” so as to “acquire most of the results.”[34]

Guy Williams, a self-taught modernist painter and art teacher, critiqued LACMA’s initiative in the pages of *Artforum*. While not opposed to art and technology per se, Williams rejected the idea that any museum—let alone “the participating corporations manufacturing for the War Machine”—should decide the future of art. Instead, he suggested archly, maybe LACMA and NASA could jointly send an artist into space thus abolishing “any minor differences that might still exist between science and art.” Or, since LACMA seemed determined to promote “art in service to the Establishment,” perhaps it could partner with the Los Angeles Police Department and the California Flower Growers Association. Together, they could make a giant mechanical cop, covered in flowers and wielding a truncheon to “pound the papier-mâché heads of daisy-plated demonstrators” at Pasadena’s Rose Bowl Parade.[35]

Tuchman labored to educate their community about his larger goals. Art and Technology, he later said, was “an *experiment*” (as opposed to “mere ‘art making’”), which needed to “be made coherent and explicit in order to be validated.”[36] Hence, the contract. Only Claes Oldenburg, a New York-based artist whose stock was rising rapidly, seems to have offered much spirited opposition. In a long list of counter-demands, Oldenburg noted that LACMA’s program, like E.A.T., would “influence future collaborations.” Therefore, securing an “honorable” contract was “an integral part of the collaboration of art and technology." His demand was a larger honorarium and first-class plane tickets. The cowboy curator stuck to his guns.

Gradually, word began to circulate about LACMA's new program. Grace Glueck at the *New York Times* had been writing mostly favorable articles about art and technology since profiling Klüver in 1965. Besides highlighting "art world luminaries"—Roy Lichtenstein, Rauschenberg, and a joint effort by Robert Irwin and James Turrell—LACMA had recruited, Glueck stressed its "experimental" nature. "If the imagination of corporation personnel can't co-exist with the artist's creativity," Tuchman told her, "then we'll learn that maybe artists should stay in their own studios."[37] On the West Coast, critic Henry J. Seldis applauded Tuchman's "selectivity" in the face of an "increased tempo of art-technological experimentations" that served to both "expand the artist's options and to open the engineer's mind." There still remained, Seldis noted, the challenge of distinguishing between "undeniable creative advances and sensational gadgeteering novelty." Klüver would have approved of Seldis's suggestion that these collaborations could ultimately help technology "move closer to the core of human existence."[38]

The existence of two prominent art-and-technology efforts running in parallel naturally invited comparisons. At first inspection, E.A.T. and LACMA's Art and Technology Program appeared similar. From a technical perspective, the input of electrical engineers would prove central as the work of art, in both senses, was electrified. The premise of collaboration was central to both efforts that were, their advocates said, best understood as experiments with final outcomes difficult to predict. Likewise, the emphasis in both endeavors was on the creative process itself, not the product (as Klüver had said, "We're not interested in art"). However, as a curator, Tuchman was certainly eager to see "production of very good and original art" as he, more than E.A.T., took a more elitist position as to who was a *good* artist.[39]

As he contacted industry leaders to secure support for his program, Tuchman deployed rationales similar to what Klüver and Rauschenberg had used for E.A.T. Funding for the arts, he noted, remained miserly but corporate largesse could address this. Meanwhile, "exposure to creative personalities" might benefit companies "in both direct and subtle ways."[40] Sensing an opportunity that transcended passive patronage, *Business Week* reported how company leaders were starting to see sponsorship of artists as a way for "conveying the excitement of engineering and scientific advances to the public." Making a comparison to industry's investment in curiosity-driven research, some executives pointed to value in supporting artist-engineer partnerships. "Anything that might come out of electronics, technology, and art," one manager at RCA noted, "is something we ought to have a stake in." Having an artist-in-residence could likewise boost company morale, suggested Lockheed's president, while artist-engineer partnerships could have a "catalytic effect on each other's ideas."[41]

Although the motivations expressed by their corporate patrons might have been similar, nonetheless E.A.T. and LACMA were pursuing different strategies.[42] For starters, E.A.T.'s supporters were constantly on the prowl for money to support the group's growing ambitions. Tuchman, on the other hand, had the implicit backing of a major museum and wealthy patrons. In principle, E.A.T. presented itself as a neutral matchmaker, willing to connect just about any serious artist with an engineer or technician. Tuchman, meanwhile, already had a list of well-established artists in mind whom he sought to entice into his project. Seen another way, E.A.T. sought to establish pairings between *individuals* whereas LACMA's program aimed to connect specific artists with *corporations*—what Tuchman termed the "one artist-one company nexus"—such that calling his initiative Art and *Industry* would have been just as appropriate.[43]

At the more fundamental level, Klüver and Tuchman expressed dissimilar attitudes toward engineers and scientists. For Klüver, of course, technologists were an essential component who could benefit personally and professionally by partnering with artists. Tuchman's invitations were not extended to engineers but rather their managers and bosses. In reading his report, one senses an obligation on the part of the technologists to follow their orders.[44] The "incredible resources" Tuchman saw in California was less about engineers' professional skills than it was deep corporate pockets. Years later, he still identified artists as "superior people" vis-à-vis the engineers they partnered with.[45] Consequently (except for luminaries like Feynman) Tuchman tended to treat the technologists who participated in LACMA's project more as functionaries following company orders—invisible technicians—rather than equal partners.

In 1969, Tuchman's initiative received a new burst of publicity after he was contacted by the United States Information Agency (USIA). This Cold War-created organization carried out "public diplomacy" using radio broadcasts and traveling exhibits. World's fairs and expos had long been a tool of "soft power" for conveying cultural values and economic prowess.[46] USIA officials were in the midst of planning the United States' official pavilion at the upcoming Expo '70 extravaganza in Osaka, Japan. Architect and designer Jack Masey—who helped set the stage for the famous 1959 Kitchen Debate between Vice President Richard Nixon and Soviet

Premier Nikita Khrushchev at the American International Exhibition in Moscow—was spearheading the efforts.[47] (Coincidentally, Julie Martin, a member of E.A.T.'s staff who later shared in a domestic partnership with Billy Klüver, was a student guide at the Moscow exhibition.) Individual exhibits planned for the US Pavilion in 1970 included moon rocks and other artifacts from the Apollo program. All of this would be housed within a giant futuristic building, oval-shaped and covered by an enormous inflatable roof, through which USIA expected millions of visitors to circulate.[48]

The question for American propagandists was how to make their pavilion stand out among the pack of other "quivering, flashing, pulsing, and shimmering exhibits" they expected.[49] Articles in the *New York Times* had brought Tuchman's Art and Technology Program to Masey's attention and, after Nixon's election, boosters from California (the new president's home turf) lobbied for the state's prominent representation at Osaka.[50] Some Nixon supporters even suggested that the marriage of art and technology resonated with Nixon's campaign promise to "Bring Us Together."[51] With exhibit space to fill and a rapidly growing arts museum now representing the Los Angeles region, Tuchman and Masey were soon negotiating terms.

By summer's end in 1969, LACMA announced that some pieces the Art and Technology Program produced would be included in a "New Art" show and placed in the official American pavilion at Osaka. The news came with two caveats. First, Tuchman's art-and-technology show at LACMA, originally planned for 1970, would have to be postponed a year. That part was easy. More challenging was the fact that the American pavilion would open in less than a year. For a "Bronx cowboy with fantastic vision" who had "climbed aboard an already saddled Los Angeles, whipped off the blindfold, and yelled, 'Let 'er buck!'" Osaka offered Tuchman a chance to show off his curatorial skills. But it didn't mean the ride wouldn't be bumpy.[52]

A DIVINITY OF WONDERS

The art-and-technology movement drew people to it for many reasons. Its focus on experimentation and collaboration attracted some devotees. The possibilities inherent in working with new materials and processes pulled in others. And, for many, merging art and technology offered opportunities for personal growth and professional development. For physicist Elsa M. Garmire, all of these factors enticed her to join the burgeoning art-and-technology community emerging in Southern California.

Born in 1939, Garmire grew up around Buffalo, New York. Her father was a chemical engineer and her mother taught music. The launch of Sputnik in October 1957, during her freshman year at Radcliffe College, brought renewed public attention and lots of federal funding to science and engineering. But Garmire had decided years earlier to pursue a science career, a decision which made her stand out among classmates who tended to gravitate toward the humanities. Garmire remained in Cambridge for graduate work in physics at MIT. Her advisor, Charles H. Townes, was a key figure in the invention of the laser, research which earned him a share of the Nobel Prize in Physics in 1964. Garmire's own research on ruby lasers—chosen partly because of the "fascinatingly beautiful" red light they made and also because the topic itself was so new—required her to design and build clever lab experiments. In August 1965, two weeks after her first child was born, Garmire defended her dissertation. The next year, she and her husband (also a physicist) moved to Caltech where she took up a postdoctoral appointment in electrical engineering.[53]

Her new academic environment was markedly different from what she had experienced at MIT. When Garmire arrived in Pasadena, the school had only a few women graduate students and no women undergraduates. Just as Caltech's leaders fretted over how to boost the school's offerings in the humanities, admitting women was framed primarily in terms of placating the school's male students. Women, they reasoned, offered potential social partners for male students while their "liberal-arts-mind" could expand the intellectual horizons for Caltech's "eunuchs of science."[54] Her husband—he was on Caltech's tenure track, though she wasn't—worked long hours and Garmire had few friends and no other women scientists at Caltech to provide mentorship. With a marginal and temporary position in an engineering department, Garmire found Caltech unsatisfying. She set up her own laser laboratory but judged her results "not terribly impressive" compared to what she had been used to at MIT. Feeling "stifled and unsuccessful" Garmire started to look for more satisfying outlets for her skills.[55]

Garmire learned about E.A.T. in 1968 from Barbara T. Smith, an artist from Southern California who was acquainted with members of the Judson Dance Theatre. Smith had recently started making avant-garde art using a Xerox copy machine she had installed in her Pasadena dining room. One of the first American artists to experiment with this new technology, Smith combined images of family photographs, food, household objects, and her own body into a series of handmade books she titled *Coffins*. Smith was also in the midst of a career switch and a difficult divorce, personal conditions which must have resonated with Garmire.[56] One day

Figure 7.2 Physicist Elsa Garmire, in her Caltech lab, ca. 1970, making laser art. Image courtesy Elsa Garmire.

in 1968, Smith stopped by unannounced at Caltech and asked Garmire to show her a laser.

Garmire herself was starting to experiment with using her optics equipment outside of the traditional laboratory context. For example, with help from a Caltech student, she moved an argon laser, a sophisticated piece of equipment not normally deployed outdoors, to the base of Millikan Library. She directed its beam up the side of Caltech's tallest building to a mirror on the roof where it was reflected back to a second mirror on the ground, sending the beam off into the night sky. (Regulations forbidding this sort of activity had yet to be written.) As she later recalled, the whole exercise was "true to my understanding of the concept of 'process, not product.'"[57]

Garmire's interest was piqued further in the summer of 1968 when an E.A.T. representative visited Los Angeles. Garmire gave a holography demonstration and, in turn, learned that E.A.T. wanted to hire a technical director for its East Coast office. Tied at the time to California, Garmire suggested a compromise. She would keep her position at Caltech while working part-time for E.A.T. As she wrote in her cover letter, she didn't share the belief "that science is the best answer to the problems of the world," but rather thought that using technology "in a non-logical artistic way" could offer open-minded scientists "new directions of thought."[58]

When Klüver learned of Garmire's interest, he invited her to join a panel titled "Art and Science—Will There Be a Difference?" at the annual meeting of the American Association for the Advancement of Science. One of two panels on art and science held that year, Garmire found herself sharing the microphone with Klüver, Gyorgy Kepes, and Jack Nolan. They were joined by Mel Bochner, whom E.A.T. had just placed at a northern New Jersey company as an artist-in-residence, and Robert Whitman, whose recent experiments with lasers as a new art medium secured him coverage in *Time*.[59] The publicity stirred by the now-iconic "Earthrise" photo Apollo astronauts had recently captured prompted Garmire to remark that the public's appreciation of NASA would be enhanced if the space agency included artists on its missions. Scientists and engineers, she said, too often approached problems by adopting restrictive boundary conditions that simplified their complexity. Artists, as she understood them, adopted no such limitations, a practice that might offer technologists a "more expansive view."[60]

Garmire later recounted how she "entered the world of art at the very top." Through Klüver, she soon met Robert Rauschenberg, who was regularly making trips to Gemini G.E.L., a new printmaking workshop in Los Angeles, and gave him a tour of Caltech's labs. Rauschenberg, in turn, introduced her to such artists as Ed Ruscha and Claes Oldenburg and helped get her invitations to parties where artists gathered.[61] The expansion of Garmire's social and professional worlds coincided with the establishment of E.A.T.'s chapter in Los Angeles. Once organized, E.A.T./L.A., as it became known, quickly became one of the most active local groups, drawing in some 500 artists, students (including Stephen Nowlin), engineers, and curators from the region.[62]

Garmire helped organize one of the chapter's first major activities, an event which coincided with the Apollo 11 mission in July 1969. Members of E.A.T./L.A. presented the "Cybernetic Moon Landing Celebration" as a "multi-media environmental performance" that would "artistically express the significance of the historic moon landing."[63] Joining Garmire in the effort was Ruth Baker, an artist interested in lasers and film who would soon become the chapter's new president, and Caroline Hinkley. Also married to a Caltech scientist, Hinkley disliked the patronizing way the school treated women. Likewise, she was trying to balance domestic and career obligations (in this case, finishing an MFA degree at nearby Claremont Graduate University while pregnant with her first child). For Hinkley, the traditional painting and drawing techniques she was learning were starting to pale in comparison to what the merger of art, science, and technology offered.[64]

The lunar landing celebration took place on Caltech's campus as Neil Armstrong and Edwin "Buzz" Aldrin were preparing to descend to the moon's surface. (A similar multimedia celebration took place in New York's Central Park but on an even larger scale.)[65] Compared to the "dust-mote efficiency of Apollo 11," the Pasadena event was "all pleasant [and] poetic." Barbara Smith constructed a long corridor using white cloth banners onto which she projected lunar images accompanied by electronically generated sounds. Acrobats lit by "motion-stopping strobe flashes" tumbled through it, giving their interpretation of floating through space. In a campus stairwell, dancer Steve Paxton, who had participated in *9 Evenings*, lay motionless to the sound of Beethoven's *Moonlight Sonata* while dressed all in blue and illuminated by spotlight. Meanwhile, Garmire, wearing a gold lamé suit, displayed a multicolored "laser wall" she had designed. Its blue, green, and red beams appeared solid, "sometimes metallic, utterly straight [and] infinitely long." Overall, a reporter concluded, the result was a "dreamy kind of fun that was nothing if not moony."[66]

When she first approached E.A.T. about a job, Garmire stressed that she was no "amateur artist" seeking to dabble. Instead, she described herself "purely a professional engineer" who wanted to make "our technology available to artists." Over time, Garmire recalled how involvement with E.A.T. "enlarged my own personal definition of art."[67] She also started to give greater consideration to the relationship between technology and society. In 1969, she wrote a short essay for a new "Technological Studies Program" at a local state college campus. Titled "Ruminations of an Engineer," Garmire admitted that trying to "comprehend technological wonders through technical education" had become "hopeless." Systems were too complex and technological change too "rapid and incomprehensible," while, in classrooms, engineering students confronted "intellectual inertia." A remedy could be found, however, in "technological art." Finding irrelevant and irreverent uses for technology offered a "first step toward eliminating this divinity of technological wonders."[68] Echoing Klüver's long-standing claim, Garmire maintained that artistic practices could humanize technological systems as well as the engineers entrusted to manage them.

Garmire was already putting some of these ideas into practice. She found that she could shine beams from lasers in her lab through different diffraction media and then photograph the results or record the images directly on photosensitive paper. The static images she generated (Garmire called them "lasergrams"), with their luminous and amorphous mingling of colors, resembled snapshots of works made by artists like Thomas Wilfred or Frank Malina. After experimenting with various processes in her lab, Garmire exhibited her work at a gallery in West Hollywood not far from where the now-defunct Ferus Gallery once was.[69] Although the aesthetics were judged "conventional," one art critic noted that laser art, with its "twisting webs of geometric color," nonetheless possessed "an aura of technological romance."[70] Garmire had done her experiments very much in the romantic tradition of the lone artist in her atelier (in this case, however, a lab at one of the world's preeminent research institutes and surrounded by expensive instruments). However, Garmire had also become deeply involved with a massive new art-and-technology initiative, one much more in the spirit of the Big Science projects that her fellow Cold War engineers and physicists knew all too well.

PEPSI'S GOT A LOT TO GIVE

Billy Klüver touted the new opportunities that would arise when corporations supported the making of new art, rather than just investing in old art. But, in his 1968 lecture at the Museum of Modern Art, Klüver had mentioned no specific companies by name. However, just about a month before his talk, an announcement in the *New York Times* signaled a momentous new project for Klüver and his colleagues. Nestled amid a dance review and an advertisement for a speed reading course, was news that PepsiCo International had given Experiments in Art and Technology a modest grant of $25,000 "to explore educational techniques for communicating with young people."[71] By the time Pepsi ended its relationship with E.A.T., the company's investment had climbed to over $1.2 million. This support enabled the art-and-technology group to undertake a project vastly more complex than anything attempted before. It also strained E.A.T.'s still-maturing ability to mediate effectively between artists, engineers, and industry.

In ex post facto accounts, some writers (including Klüver) portrayed E.A.T.'s engagement with Pepsi as a reluctant, even random act. But E.A.T. clearly saw Expo '70 as a timely opportunity.[72] As early as February 1968, E.A.T. reached out to Jack Masey, who was deep in the throes of planning the official pavilion for the United States. Masey, obviously, had considerable influence over what the US exhibition would include. An internal memo, copied to Klüver and Rauschenberg, noted that

Figure 7.3 E.A.T. staff in 1969. From left to right in back: Winnie Bellaar Spruyt, Peter Poole, Julie Martin, Frances Melita, Billy Klüver, Claudio Badal, and Lucy Re. Seated on the floor, from left to right in front: Susan Munshower, Gloria Malerba. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

"Masey says we must do at once a huge exhibit which will be a wow and he will take it! Maybe." However, Masey noted that his organization probably wouldn't select any art for Osaka that "hadn't proved itself first here at home."[73] But if E.A.T. could then pull off some other highly visible project at Expo '70, it would validate E.A.T.'s role as a cultural broker. Helping humanize technology for millions of the fair's visitors might also, with any luck, give the organization greater financial stability.

Pepsi executives also perceived Expo '70 as an opportunity. In return for advice on how to manage the fair's dining concessions, Expo '70 organizers in Japan had given the company, which had less than 10 percent of the soft drink market in that country, permission to construct an independent building set apart from the main Festival Plaza. (Only two other American companies, Eastman Kodak and IBM, were likewise favored.) Moreover, Pepsi received a prime location where the company's pavilion would serve as a natural meeting place for the millions of people streaming in to experience Expo '70.

Overseeing this quid pro quo was Alan Pottasch, head of Pepsi's Japanese branch. He had been the driving force behind the company's successful "Pepsi Generation" advertising campaign, with its jingle: "You've got a lot to live / And Pepsi's got a lot to give." Pottasch hired a venerable Japanese construction firm to design and build the basic shell for the Pepsi Pavilion. The company's architect produced a striking design that improvised on the geodesic domes Buckminster Fuller had popularized in the 1960s. A 120-foot-diameter structure, made of white plastic panels over a steel frame, presented a faceted exterior that one artist described as a "Buckled Fuller dome." However, the low opinion E.A.T. members had of the building's appearance—"we all hated that dome," said one member—would later catalyze the creation of the pavilion's most noteworthy visual signatures.[74]

Already primed to participate in Expo '70, E.A.T.'s collaboration with Pepsi began as a conversation between two neighbors in the suburbs outside of Manhattan. David Thomas, a company vice president who had been handed the Pepsi Pavilion project, was stumped. His company's last major exposition had been produced by the Walt Disney Corporation. While quite popular, Disney's "It's a Small World" attraction, for the 1964 New York World's Fair, exceeded Pepsi's original budget by several million dollars. This added to a sense of unease among Pepsi executives who were already coping with a corporate culture where vice presidents were regularly hired and fired. To keep things simple and cheap, the company's initial plan was an auditorium where film screenings and music concerts could be held. Pottasch even suggested hiring Disney again. Thomas, however, argued this was a "terrible idea" that wouldn't charm the youth market Pepsi wanted to reach.[75]

Pepsi wasn't the first company to consider working with contemporary artists in order to produce a spectacle for an international exposition. For Expo '58—the world's fair in Brussels—the Dutch electronics company Phillips contracted with Le Corbusier for its pavilion. The project, largely overseen by the Greek architect and composer Iannis Xenakis, evolved into a multimedia spectacle presented inside an innovative building made of precast and curved concrete shells with over 300 speakers fixed to its interior walls. The visual imagery visitors experienced inside, some of it by filmmaker Philippe Agostini, was accompanied by a six-minute piece of experimental music called *Poème électronique* that Edgard Varèse had composed. In seeing their pavilion built, Philips's executives had to balance company interests and budgets with the artists' ambitious objectives, information that might have benefitted Pepsi's leaders.[76]

Professional artist Robert Breer lived near David Thomas. His father had designed the streamlined Chrysler Airflow, an iconic modernist form that artist Claes Oldenburg later appropriated for one of his soft sculptures. Born in 1926, Breer grew up, "surrounded by engineers" and even studied the subject himself at Stanford before becoming an experimental filmmaker and sculptor. In 1955, while living in Paris, Breer exhibited some of his work in "Le Mouvement," the show at Denise René's gallery that influenced Frank Malina. Breer had known Klüver for years but *9 Evenings* had left him wary about big collaborations. Moreover, he disliked the hype and commercialism that came with fairs like Expo '70 so he was open to unconventional, perhaps more contemplative, ideas.[77]

When Thomas and Breer first talked, the artist was in the midst of fabricating an art series called *Floats*. These Styrofoam sculptures were self-propelled by hidden, battery-powered motors such that they seemed to hover just above the ground. If they encountered resistance when they moved about, they could reverse their almost imperceptible motion. Carefully placed to encourage a meditative state, Jack Burnham once likened them to the stones in the rock garden at Ryōan-ji Temple in Kyoto. Rock music, sculptures as rocks, and a shared interest in Japanese culture (Thomas's father had briefly been a Shinto priest in Kyoto) started to coalesce as they spoke. Breer knew Klüver had extensive experience interacting with companies and described how E.A.T. could operate as "some kind of buffer" between the various stakeholders. Klüver, meanwhile, was preparing to quit Bell Labs and work full time as E.A.T.'s president. So, when Breer contacted him in mid-September, the phone call immediately got his attention.[78]

What David Thomas heard about E.A.T. intrigued him. Klüver made it clear from the outset that his group didn't intend to outfit some modish dance hall with a psychedelic light show to accompany rock concerts. Although reluctant to discuss specifics, Klüver intimated that something "interesting" could probably be done for $350,000. The Pepsi executive countered with a more generous budget proposal: half a million dollars, just "to be safe."[79] Working with Pepsi, of course, would present many interfaces—between artists and technologists; between Pepsi and E.A.T.; and between scores of American businesspeople, engineers, architects, journalists, and artists, as well as their Japanese counterparts. Klüver suggested at first that E.A.T's role best be limited to mediating and managing activities as E.A.T. was more of "an experiment in organization" rather than a group for hire that made art objects per se.[80]

A few weeks later, Klüver and Breer took Thomas to the Electric Circus in the East Village. Part discotheque, part experimental theater, the hipper-than-hip nightclub served its guests a trippy cocktail of imagery and sounds. On some nights, Andy Warhol's Exploding Plastic Inevitable took over the space with the Velvet Underground acting as the house band.[81] By coincidence, at a bottlers' convention in Manhattan that autumn, Thomas also experienced a performance by USCO (derived from its longer name, "The Company of Us"). This was an art collective that blended the avant-garde with psychedelia and hippy mysticism via light shows and surround sound effects.[82] Thomas, slowly dropping the idea of Pepsi's pavilion as a dance hall, began to imagine that some combination of the Electric Circus and USCO—with E.A.T. managing the process—could produce something acceptable to his bosses.

Klüver, meanwhile, had begun to reconsider E.A.T.'s responsibility. The engineer noted privately, "Let's assume we can get what we want from Pepsi if we make the suggestions early." He told Thomas that Bell Labs could build better equipment than what USCO offered as he realized that managing other groups, especially those which he believed took commercial advantage of artists' ideas, might not be the best role for E.A.T. As an alternative arrangement, E.A.T. could gather well-known artists who would jointly design "an integrated environment" for Pepsi. Then, the company could take over the project with E.A.T. offering advice as needed. But, despite Klüver's insistence that E.A.T. didn't intend to compete for Pepsi's patronage, that was indeed what happened.[83] In November, Pepsi asked E.A.T. and the Electric Circus to present their ideas to company executives a month later.

Robert Breer, increasingly intrigued, assembled a core group of artists. Besides himself, this included musician David Tudor and artist Robert Whitman. Poet-artist Gerd Stern from USCO occasionally joined brainstorming sessions while Klüver brought in engineers Fred Waldhauer and John Pan from Bell Labs. Forrest "Frosty" Myers was a new addition. Born in Southern California, Myers had recently moved to New York where he joined E.A.T. and established himself as a promising experimental sculptor with the Park Place group, an arts collective that incorporated mathematical and scientific concepts in their work.[84] Breer knew of his experiments making sculptural forms via large searchlights. Like Robert Whitman and Elsa Garmire, Myers also saw artistic potential in the steady, intense glow of light that lasers provided. Sketches he made as early as 1963 show he was aware of their possibility as a future art medium. In the summer of 1967, he realized this with a site-specific work he designed for the New York nightclub Max's Kansas City. One idea he had was to generate a laser beam at his studio and send it two blocks away, down Park Avenue South, to the famous nightclub where it would hit a mirror attached to a jukebox. Vibrating at a frequency that changed with whatever song was playing, the result would be an ever-changing light show projected on the club's back wall.[85] Eventually, Myers's installation "played" nightly at Max's, helping entertain guests well into the 1970s.

Naturally, the artists' ideas reflected their current activities. Myers was experimenting at the time with outdoor installations using searchlights, Breer had his slowly moving cybernetic floats, and Whitman was increasingly intrigued with lasers, optics, and visual perception. The engineers added some ideas of their own that caught the artists off guard. John Pan, an African-American engineer who worked on digital transmission systems, proposed creating "international love nooks on the dome" and adding "wind tunnels and waterfalls," which visitors could use to enter the pavilion.[86] But everyone accepted Whitman's basic premise that, unlike the 1964 world's fair, the pavilion should not be "a morally degrading experience." Instead, making the pavilion's design *and* the visitors' experience flexible—sort of an aesthetic "choose-your-own adventure"—was both desirable and democratic.[87] In a sense, what the artists and engineers were proposing was an "anti-pavilion," an adaptable and experimental space that expressed irreverent, noncommercial, and antiauthoritarian values. They even briefly proposed that the dome itself should be painted black, the opposite of Pepsi's design and a color long-associated with anarchy. For a conservative corporation like PepsiCo—Calvin Tomkins described the company's leadership as "very right wing" and full of "Agnew Republicans"—E.A.T.'s rebellious attitude portended future friction.[88]

Despite agreeing on basic principles, Breer recalled the group's first meetings "were hard on the various egos." Each artist pushed his own vision and disparaged competing ones until "we were barely cordial."[89] Finally, with time running out before their presentation to Pepsi's executives, two new ingredients helped the artists and engineers move beyond their stalemate. Jack Masey suggested that Klüver meet with John Pearce, a young architect who had gotten his degree from Yale only a few years earlier. Pearce, who had been working temporarily on Masey's project, had actually been to Osaka and inspected the site where Pepsi's pavilion would be built. The architect quickly realized that Breer and the others were in over their heads. "They didn't seem to realize they were really building a building," he later said, as nothing other than Pepsi's basic quasi-geodesic design had been approved. This, he suggested, could be turned to their advantage as it gave the artists and engineers lots of options. Pearce also described the site for the entire expo, which resembled a bowl with small lakes in the middle and the various national and corporate pavilions situated on the slopes. The Pepsi Pavilion, he said, would occupy a "beautiful position," relatively isolated in an open area with great potential "to be recognized and appreciated."[90]

As the artists continued to dither, Klüver added the second key ingredient and invited Robert Rauschenberg to participate. As he had with other E.A.T. projects, Rauschenberg encouraged everyone to imagine beyond their own ideas and experience. For example, they were still thinking almost entirely in visual terms. "We're all painters," Klüver recalled him saying, "so let's do something non-painterly." What emerged from the rejuvenated design process was the notion of the pavilion as an "invisible environment," where visual inputs would be accompanied with other impressions to create a total sensory sensation.[91] This idea resonated with Pearce, who liked the idea of visitors creating their own personal experience, whereas the other pavilions for Expo '70 were based more on "shoving people through on moving belts."[92] This idea of "environment" also resonated with Japanese artists, some of whom would later work with E.AT. on the pavilion, experimenting themselves with "intermedia art."[93]

Rauschenberg's intervention prompted a flood of fresh suggestions. Why not make areas where the temperature changed? Perhaps build pods that functioned as anechoic chambers, creating spaces of total silence. Maybe the floor inside the pavilion could have zones where one heard particular sounds or where rear-screen projections might give visitors the experience of "walking over" flames, clouds, or fish. What if the floor itself could be faintly sloped so that visitors would subconsciously become more aware, even unsettled, by their surroundings? But central to all of these ideas was E.A.T's determination to create a space where visitors could choose *what* to experience. Such an experience would remain, as Myers called it, "pure." By this, he meant that the artists and engineers "could maintain aesthetic control" and "there wouldn't be 'Buy Pepsi' all over everything." The pavilion would offer "no tricks, just a whole experience."[94] As E.A.T. later learned, translating abstract concepts like "purity" and "total environment" into Japanese challenged Pepsi's public relations team. The company briefly considered naming their exhibition the "Sensosphere" until a Japanese collaborator pointed out that "sensō" in Japanese means "war."[95]

Over the next few weeks, Breer, Myers, and Pearce, with Klüver functioning as a mediator, worked out the pavilion's basic design. They all agreed that the crumpled-looking exterior was ugly and boring. So, why not hide it? Someone suggested shrouding it with machine-made clouds. No one was sure how to do this but the engineers assured the artists it was possible. And, once the detested dome was hidden, some sort of interplay, Myers suggested, between light and fog would be visually striking, especially at night. Among the shafts of light and swirling clouds they imagined, Breer's slowly moving floats would create a shifting visual impression that was subtle, yet powerful.

Inside the pavilion, the artists' imperative again was to hide the dome's faceted structure. Here, Robert Whitman drew on his recent experimentation with optical effects. For example, the Jewish Museum in New York had just displayed an innovative piece called *Pond* he had made with Eric Rawson and a dozen other engineers at Bell Labs.[96] Whitman used sheets of Mylar stretched across a large frame that, thanks to electronics Rawson and his colleagues built, gently vibrated. The distorting effect was enhanced by flickering strobes while banal words and phrases were projected onto the mirrors or played through loudspeakers.[97] As viewers could see themselves amid the oscillations of sound and light, the effect was one of "gentle narcissism."[98] For the pavilion, Whitman suggested it include some sort of reflecting surface. This idea grew in importance until their conception of much of the dome's interior space centered around the presence of a large, hemispherical mirror. Properly built, the mirror would produce what a physicist would call "real images"—three-dimensional projections of objects or people appearing to hang suspended in space—which would visually blur the line between the real and illusory world.

In early December, the two contenders for the pavilion presented their ideas at Pepsi's Manhattan headquarters. The Electric Circus group, led by owner Stanton Freeman, a Canadian who previously had made high-fidelity audio equipment, gave its pitch first. Freeman arrived with scale models, written descriptions, and a two-hour exposition that was "very, very polished, a brilliant performance."[99] At least until the Pepsi executives asked about the cost, to which Freeman told them that nothing interesting could be done for less than a million dollars. (He was later found guilty for conspiring to smuggle cocaine into the United States.) Outraged and embarrassed, David Thomas waited anxiously to see what E.A.T. would present.

Thomas had been quietly nudging things in Klüver's favor by filtering the press coverage his colleagues read about E.A.T. Besides emphasizing the concrete elements of E.A.T.'s proposal, and not the conceptual ones, he stressed that, by 1970, a pavilion that offered just a fancy light show with dance music would seem déclassé. E.A.T., on the other hand, he said was "really in tune with contemporary art and artists." Nonetheless, E.A.T. representatives gave an apparently unrehearsed presentation that was, Thomas recalled, a "masterpiece of ineptitude." Myers, Breer, and Whitman—long haired, mustached, and attired in decidedly non-button-down garb—drew baffled stares from staff in the company's offices while their verbal descriptions of what they wanted to do didn't always agree. The group brought only a few "rough and fanciful" drawings while Klüver spoke abstractly about the "necessity of humanizing technology" and building an "invisible environment."

However, when the E.A.T. group took some Pepsi executives over to MoMA, the atmosphere shifted. Klüver walked the businessmen through Hultén's "Machine" exhibit. While he talked about the show, the engineer stopped to repair a malfunctioning piece with a handy pair of pliers, an intervention that surprised the Pepsi people. Robert Rauschenberg joined the group at lunch. The artist—now quite famous—impressed Alan Pottasch who especially liked Rauschenberg's technically sophisticated work called *Soundings*, recently made with E.A.T.-affiliated engineers, that was on display.[100]

Back at Pepsi's office, Pottasch asked Klüver and his colleagues for a budget. They didn't have one. Baffled, the executives gave them some time to prepare a draft. A few hours later, Klüver and the artists presented a short handwritten estimate: the hardware would cost some $468,000 (with another $70,000 included as contingency) while E.A.T.'s consulting fees and salaries would add another $321,000. Their total estimate was $859,000.[101] Pepsi countered that their ideal was about $300,000 less than this and Klüver indicated this *might* be possible. A few days, later, Thomas broke the bad news to the Electric Circus people—E.A.T. would build the pavilion.

At this point, one would expect that someone at Pepsi would have prepared a formal contract setting out the terms, scope, and budget for E.A.T.'s work. Oddly, this essential task seems to have slipped through the cracks. A few days after E.A.T.'s presentation, Pottasch asked internally for a "crystallization" of E.A.T.'s proposal—"all we have now is an 'environment'"—and a breakdown of costs and schedule, but a copy of this request wasn't sent to Klüver. Among the thousands of pages preserved from the pavilion project, the most contract-like document is a June 1969 letter from Pepsi stating that E.A.T. "shall develop, design, and complete" the pavilion, but here the cost appears as $1,235,000 (almost $400,000 more than the ceiling discussed six months earlier).[102] Moreover, Thomas was quickly replaced in New York by the "shark-like" Pottasch, leaving E.A.T. without its most sympathetic contact.[103] "I don't think there was ever a decision made about anything," Klüver later recalled, "I sometimes think they just slid into it."[104]

Pottasch later reflected that Pepsi differed from companies like General Motors or RCA, which used fairs and expositions to showcase their new models and product designs. Soft drinks didn't change from year to year so companies like Pepsi relied much more on branding and marketing. While it wasn't necessary to show a particular *thing* at Expo '70, it was "important to get across certain concepts" like "bigness," a sense of novelty, and the idea of "community."[105] Like E.A.T., Pepsi had its own intangibles it wanted to present to the public. Just as its advertising jingle said, Pepsi definitely had a lot to give.

Klüver and Rauschenberg symbolically repaid the company for its largesse a few months later when they nominated Pepsi for a "Business in the Arts" award. Their letter praised Pepsi in language sympathetic to E.A.T.'s perspective. Because Pepsi had "approached E.A.T."—a curious interpretation of the partnership's origins—an exciting new alliance had formed that would allow Japanese and American artists and engineers "to experiment" with building a "versatile environment."[106] Pepsi received an honorable mention and E.A.T. continued to pivot toward the corporate world while its individual artist-engineer pairings became less prominent.

Some months later, Klüver updated a group of executives, artists, and curators in Los Angeles about the pavilion project. "E.A.T. is interested in Pepsi-Cola, not in art," he said, "our organization tries to interest, seduce, and involve industry in the process of making art."[107] By 1969, this carefully orchestrated seduction had fashioned a *ménage à trois* of artists, engineers, and industry leaders (although, given the top-down approach used by both Klüver and Tuchman, perhaps "arranged marriage" is a better metaphor). Of course, engineers were long accustomed to working with (and around) middle management. Now, a cadre of artists—once in hell, but now in business, as Allan Kaprow had observed—could try to add this new skill to their tool box.

Even as they maintained a close eye on what the other was doing, Klüver and Tuchman adopted different organizational strategies. Klüver had wagered E.A.T's future on one company and expanded his New York-based operation into a web that spread to California and then Japan. Tuchman, meanwhile, diversified his portfolio and persuaded dozens of companies to join his museum's technoaesthetic project. Despite their distinctive approaches, Klüver and Tuchman based their parallel projects on similar ideals, such as process, collaboration, and experimentation. But in the coming months, resolving banal problems of logistics, management, and communication assumed equal, if not greater, importance. Making the art, they said, mattered more than the art made. Now, with financial commitments and media attention mounting—and deadlines looming—corporate executives, art critics, and fair goers alike wondered what they would see.

8

OVERLOAD

> As to the question of whether or not the Pavilion was worth doing, I would have said the point was moot, because the experiment about the process of new ways of working and collaborating and organizing effort was the point . . . the result was beautiful and enthralling.[1]
>
> Fred Waldhauer, 1972

In the spring of 1967, the MIT Press published Alvin Weinberg's book *Reflections on Big Science*. The author, a physicist who directed the Oak Ridge National Laboratory for almost three decades, had personally witnessed how certain scientific fields had become almost pathologically reliant on giant machines and ever-larger interdisciplinary teams. Money, in amounts unimaginable to scientists before the Cold War, gushed from military organizations, a slew of acronymic government agencies, and giant corporations. Weinberg branded these monuments of "Big Science"—"the huge rockets, the high-energy accelerators"—as the secular equivalents of ancient pyramids or medieval cathedrals.[2]

Although researchers could not have known it, the late 1960s marked a certain high-water point for Big Science. But the practice of making new knowledge with ever larger and more costly research facilities was not without detractors. After winning the 1960 Nobel Prize in Physics for inventing the bubble chamber, Donald Glaser migrated into molecular biology, believing this would allow him to spend more time *doing* science as opposed to managing it. Besides Big Science's impersonal scale, its critics lamented the dominance of team-based collaborations that diluted individuals' contributions as well as the erosion of research as a skill, akin to a craft, that one gradually learned.[3]

Weinberg identified three "diseases" that Big Science brought. "Moneyitis" resulted in researchers "spending money instead of thought." Bigger budgets came with a pressing need to justify costs and an imperative to publicize research results. Consequently, a "journalitis" emerged that privileged, if not outright encouraged, the "spectacular rather than the perceptive." And finally, Big Science's sheer scale fostered "administritis," as a bloated hierarchy of managers and bureaucrats was needed to manage the whole operation.

For years, many artists had been experimenting with new technologies, sometimes in isolation but often in collaboration with engineers. Other artists enthusiastically adopted themes and imagery from engineering and science as inspiration for their own creative processes. Likewise, concepts such as cybernetics percolated into the art world's consciousness. Even new ideas from the history of science, such as Thomas Kuhn's "scientific revolutions" and "paradigm shifts," began to appear in the writings of people like Jack Burnham. And while too few artists for Frank Malina's liking articulated their aesthetic experiments, they now had access to *Leonardo*, a journal deliberately modeled on scientific journals. Seen from this perspective, maybe it isn't surprising that some artists and critics detected some parallels to practices that originated in the scientific community.

The products of science and engineering, let alone the vast scale of money and teams devoted to producing them, were obviously not the same as art. But in certain ways, E.A.T.'s commitment to building the Pepsi Pavilion and Maurice Tuchman's administration of LACMA's Art and Technology Program offered the art world's analog to Big Science. Likewise, critics' responses to what we might call "Big Art" replicated the same concerns scientists expressed about the implications of large-scale technoscience. Weinberg had likened Big Science to a "contagion" that would absorb more and more money and attention unless it was contained. This pathology, he suggested, could eventually ruin science.[4] Might not similar influences contaminate the artist's world? Of course, both sets of claims mistakenly presumed that artists and scientists alike had once existed in some prior state of innocence, free from worldly and impure concerns.[5]

This chapter examines how Klüver's and Tuchman's projects, the two largest art-and-technology initiatives of the long 1960s, were carried out. Both of them relied on large collaborations, extravagant funding, responsiveness to patrons' needs, and an avowedly engineering outlook. While each claimed some qualified successes, these two projects stoked concerns that Big Art would soon subsume the lone artist, ruining their craft while producing artworks too closely aligned with commercial spectacle and corporate status.

BIG IN JAPAN

With the opening day for Expo ’70 rapidly approaching, curator Maurice Tuchman selected eight artists—all men—whose work would be showcased in the New Arts section of the official US Pavilion. Some of them, like Andy Warhol, Claes Oldenburg, and Roy Lichtenstein, were already stars in the contemporary art world. While not quite celebrities of the same stature, Robert Whitman and Tony Smith were well known to collectors and curators. Tuchman also included three younger artists—Rockne Krebs, Boyd Mefferd, and Newton Harrison—who were just beginning to attract national attention.

Each of the artists Tuchman recruited for Expo ’70 approached the use of technology, corporate sponsors, and engineers differently. Given that business executives (at least publicly) praised the possibility that engineers and artists might have a “catalytic effect on each other’s ideas,” I want to focus on two different manifestations of this ideal.[6] Artist Rockne Krebs, for example, became technically proficient via his close collaboration with engineers and technicians. Meanwhile, engineer John Forkner engaged with Robert Whitman to such an extensive degree that their artwork was essentially a coproduction and the overall experience fundamentally altered the technologist’s career.

Born in Kansas City, Missouri in 1938, Krebs got his BA in 1961 from the University of Kansas where he focused his attention on studying sculpture. After a stint in the navy, Krebs settled in Washington, DC and started his art career in earnest. For his first major exhibition in 1967, Krebs created a series of austere geometrical works using materials like Plexiglas and metal that revealed his attraction to sharp lines.[7] A critic for the *Washington Post* judged Krebs’s efforts “starkly courageous.”

However, in a personal reaction against the “preciousness” the marketplace placed on art objects, Krebs decided to switch to a less tangible medium. “I am interested,” Krebs told one interviewer, “in the sensation that one can have without reference to the object of art.”[8] Rather than working with natural light, as artists had done for centuries, Krebs chose to use the artificial light from lasers as his medium. It was a bold move on Krebs’s part. Given their low cost and ubiquity today, it’s easy to forget just how new (and expensive) lasers were in 1968, not to mention the fact that the technology itself wasn't widely known outside engineering and science communities. Krebs's decision also suggests how artists were increasingly experimenting with new technologies, adopting them as artistic media almost as soon as they became available.

With technical assistance from Paul Haldemann, a research associate from the University of Maryland's electrical engineering department, Krebs started his experiments using beams of red light from two helium-neon lasers. Combined with specially crafted mirrors and some artificial fog, he created the aptly named *Sculpture Minus Object*. It was first displayed at the Washington Gallery of Modern Art, a venue Walter Hopps directed after leaving Los Angeles. The laser beams traced out in three dimensions the space that an actual physical sculpture would have occupied while vibrations from guests' movements about the room subtly altered its appearance.

Hopps, aware of what was going on artwise on the West Coast, told Krebs (who had recently joined E.A.T.) about Tuchman's program. In March 1969, the artist sent a proposal to LACMA that described two possible projects: an interior piece he called *Day Passage* and an outdoor work titled *Night Passage*. Seen in the dark, for example, *Night Passage* would appear to make, Krebs proposed, "flowers grow out of the cement" in front of LACMA's entrance.[9] Realizing either of the projects, however, would take considerably more equipment and technical expertise than the artist had.

A few months later, Hewlett-Packard (HP) Labs in Palo Alto invited Krebs for a visit. Founded in 1966 by David Packard and William Hewlett, it focused on long-term research that might eventually have commercial applications for the lab's parent corporation. Hewlett-Packard's engineers and physicists were especially interested in using lasers for applications like holography or incorporation into the next generation of office printers. Krebs initially harbored misgivings about working with such a large research lab and he was unsure if the technically complex artworks he had in mind were even possible to build.[10] But the meeting went well enough that Krebs and HP's managers agreed to sign one of Tuchman's contracts.

Krebs arrived in Palo Alto to start his residency later that summer with a "reasonably good science-fiction background," but not knowing much more than how to "turn a laser 'on' and 'off.'" As he recalled, he still hadn't yet worked out the "capabilities and limitations" of the new tools he wanted to use. Laurence Hubby, a young researcher whom HP Labs had just hired, became his main collaborator. A native of Texas, Hubby had recently completed graduate work in physics at UCLA and was

art and technology

Tweaking the various prisms and beam-switching devices that control the Krebs/HP laser apparatus are, from left, optical engineer Bruce Ruff of Santa Clara Division, artist Rockne Krebs, and physicist Larry Hubby of HP Labs. HP furnished equipment, consultation, design and fabrication of the precision apparatus. In addition, some very special and hurried packaging efforts had to be made by Corporate Packaging Engineering people to make a tight delivery deadline.

Electronically timed shutter system for the Krebs laser apparatus was designed by John Lazier (standing), while Charlie Michell provided mechanical design help. It was an interesting change of pace for the HP Labs people. Krebs, who attired himself in the informal style conventional to artists, impressed the HP staffers as serious, talented and pleasant to work with.

4

Figure 8.1 Artist Rockne Krebs (center, top image) working with Hewlett-Packard engineers Bruce Ruff (left) and Larry Hubby (right). Two other engineers—John Lazier and Charlie Mitchell—who also helped Krebs are in the bottom photo. Image from *HP Magazine*, February 1970 (photographer unknown).

exploring how to build lasers that could be *tuned* so as to emit light beams of variable wavelengths or colors.[11]

Krebs spent his first few weeks in California talking to experts at HP and other companies in the Bay Area that specialized in lasers. After giving an informal presentation explaining what he wanted to create, a scientist at HP Labs whose wife was an artist asked Krebs if he had considered patenting his use of laser beams. For instance, he noted lasers could be used to mark off physical space without actually disturbing the landscape. Intrigued by the possibility, Krebs was soon talking with a lawyer about securing a patent (it was granted in 1971) for a "light reflecting apparatus" that could create "illusory architectural models."[12]

With help from optics engineer Bruce Ruff, circuit designer John Lazier, and mechanical engineer Charlie Mitchell, Hubby and Krebs designed an intricate optical system based around active as well as static laser beams. In addition to a large argon laser that emitted blue and green light, their setup also included two lower-power helium-neon lasers for red beams, a series of small, specially machined mirrors, and a fog-producing system to increase the beams' visibility. The mounts for the small mirrors (Krebs initially imagined he would need about thirty of them) proved challenging to design—they had to be unobtrusive and stable, yet fully adjustable. All told, Hewlett-Packard contributed over $10,000 worth of mirrors and other gear to the project, and, most significantly, purchased a 500 milliwatt argon laser for Krebs to use. These acquisitions, plus the extensive time that Hubby and other technologists contributed far exceeded the company's original $7,000 donation.

Krebs designed his piece for Expo '70 to fit within the large parallelogram-shaped room he had been assigned inside the US Pavilion. A spectator would encounter an "infinity reflection" space created by beams of light from the two red lasers bouncing between large mirrors. This was relatively simple to create compared to engineering the effect from the argon laser. At the time, argon lasers were complicated and heavy pieces of equipment. Besides the laser itself, a bank of electronics and a water-cooling system was needed to operate it. Krebs's design called for the color of this laser's beam to alternate between blue and green while it was projected at different angles. To make this happen, John Lazier built an electronically timed shutter system that controlled the beam's color and configuration. This specially designed optical system allowed Krebs to "weaken the psychological persistence with which laser beams are perceived as apparently *real matter*," he later wrote, as the green and blue light would vanish and then reappear in another location.[13]

As he shuttled between his studio in Washington and Palo Alto, Krebs learned from Hubby the fundamentals of how his equipment worked. This was essential because the artist would be responsible for assembling and operating the gear by himself. The night before he left for Japan, Krebs and Hubby, who by now had invested several weeks of work in the project, stayed up late testing everything and making last-minute adjustments. The next day, Krebs traveled to Osaka where he started building his installation. Over several days, working alone and at night (a schedule necessary to avoid vibrations from the ever-present construction activity) Krebs meticulously positioned his lasers and mirrors to create the variable sculptural effects he wanted.

Photographs are unable to adequately convey the visual experience of Krebs's light-and-space environment and, of course, he had designed it so it transformed itself over a set cycle of time. It was probably the very first time many Expo '70 visitors had ever seen a laser in person. One art critic described how, on entering Krebs's S-shaped installation, he was "confronted with a red wall of light" that the helium-neon lasers created. Meanwhile, a prism split the argon beam, emitted from a hole Krebs carefully drilled in one of the large wall-mounted mirrors, into "glowing and immaterial planes" that visitors passed through. As the colors cycled between deep blue and vivid emerald, intangible structures appeared and then dissolved, gradually building to a "silent visual crescendo" that contrasted with the static "sculptural armature" provided by the red laser beams.[14] "The path the light beams take," Krebs later described, "is the sculpture. It is a piece of sculpture that one could physically move through."[15]

Krebs's collaboration with Larry Hubby and other engineers at HP provided him with essential knowledge he needed to make his piece work. The two men got along well and each of them took something away from their interactions. For Hubby, the dividend was personal. He recalled how Krebs encouraged him to grow his hair a little longer and dress a little hipper (changes which one bemused lab manager noted in a performance review) while the collaboration enhanced Hubby's respect for artists' research processes.[16] Krebs also learned a great deal, albeit it on a different wavelength. "It was stimulating for me," he told Clare Loeb in a radio interview in 1971, "because I wasn't talking about art all the time. . . . Here was this whole new arena of information, of knowledge."[17]

The technical skills Krebs picked up from Hubby and the other HP staff continued to pay off after LACMA's Art and Technology Program ended. Before his death in 2011, the artist made dozens of sculptural installations using lasers (as well as other optical media such as neon light and sunbeams). After Gyorgy Kepes invited him to spend a year at the Center for Advanced Visual Studies, Krebs's constructions became increasingly ambitious as he shifted away from gallery shows to making monumental public artworks.[18] For example, *The Green Hypotenuse* (1983) centered around a green laser beam stretching seven miles from an astronomical observatory on nearby Mount Wilson down to Caltech's campus. Krebs's artistic experiments reflected Lucy Lippard's and John Chandler's observations that art was increasingly "dematerialized." Based on the emergence of conceptualism and other movements, they proposed that the traditional assumption that art meant physical objects might, in time, become "wholly obsolete."[19] The pieces Krebs executed were deliberately ephemeral. When Krebs switched off his lasers, nothing remained but sketches, critics' assessments, and spectators' recollections.

If Larry Hubby's supervisors at Hewlett-Packard were perplexed by his new clothes and hairstyle, it's hard to imagine what administrators at Philco-Ford's Aeronutronic Division thought of John Forkner's bushy red beard. Regardless, it was the engineer's chest-length facial hair that first brought Forkner and Robert Whitman together. "What are managers going to do with an artist?," Whitman recalled. "They introduced me to all the guys with beards. John Forkner had the longest beard. So we talked."[20] Over the next several months, Whitman and Forkner developed an exceptionally close rapport. When Los Angeles radio host Clare Loeb interviewed them in 1971, for example, the two collaborators often finished each other's sentences as they enthused about their work together.

Forkner, as noted earlier, had dabbled in art making for some time. But after he joined E.A.T., his interests took a more serious turn. In October 1968, for instance, he filed a patent application for a device that made "esthetically pleasing patterns of light which is controllable like a musical instrument." Forkner's "light display instrument," as detailed in the patent he received about three years later, shared similarities with devices that electro-kinetic artists such as Thomas Wilfred and Frank Malina had built.[21] Years later, Robert Whitman recalled sitting in a car with Richard Feynman who, in his thick Queens accent remarked, "Boy, where did you get this guy? He's terrific!"[22]

When he first started spending time at Philco-Ford, Whitman tried talking to as many engineers as he could, but security restrictions—the company was primarily a defense contractor—put constraints on his explorations. Consequently his fragmentary ideas drifted back to optics, something he had already experimented with for his piece *Pond*. "I've always been interested in ghosts and spirits . . . ethereal images,"

Figure 8.2 John Forkner (left) and Robert Whitman (right) at Philco-Ford Corporation. Photo courtesy the LACMA archives.

he later explained.[23] One idea he had was to display "familiar inanimate objects in an unusual context." For example, a heating element reflected by a spherical mirror (the term refers to the curvature of the reflecting surface, not its actual shape) would create a "real image" of the object. If it was possible to also focus heat to the same spatial location, then "the viewer would get the surprise of discovering that the ghost-like image of the heater was actually hot!"[24]

Forkner was initially puzzled by Whitman's interest in what he considered "seemingly trivial phenomenon," until one day he set up his own spherical mirror in his lab and reached his hand toward its center of curvature. "The very realistic, three-dimensional image of my hand that seemed to come out of the mirror was so startling," he noted, "the effect of touching the image of your forefinger without receiving a touch sensation came as a complete surprise." Forkner recalled this moment as the real beginning of his collaboration with Whitman. It helped him understand the artist's goals while Whitman was learning to better articulate technical questions that came out of his artistic ideas.

One day, over some afternoon cocktails, the two of them began debating what it would be like to see the world turned inside out. This optical effect—what engineers call "pseudoscopic imaging"—was explored, Forkner later learned, by the British scientist Charles Wheatstone in the mid-nineteenth century while he was investigating binocular vision. In addition to inventing the stereoscope, which uses two separate images to create a single three-dimensional picture, Wheatstone also built a pseudoscope, which caused solid objects to appear hollow. With Whitman intrigued by the idea of showing objects and faces as if they had been turned inside out, Forkner justified to his managers that this "space-inverting property" could "be especially interesting technically" for the company's current work in holography.[25] It was perhaps a stretch, but stranger Cold War-fueled research ideas had proven profitable.

Unfortunately, efforts to fabricate a wall-size pseudoscopic mirror proved impractical, so Forkner started experimenting with alternatives. Driving home in heavy traffic one night, he thought about the optics of automobile taillights. This led to his idea that Whitman's piece should incorporate an ensemble of small "corner reflectors," which bounced light back to its source via three mutually perpendicular flat surfaces. Instruments using retroreflectors, Forkner knew, were regularly used for surveying and were part of the Apollo program's Lunar Laser Ranging experiment. Whitman's installation eventually included an array of some 1,000 corner reflectors, which presented visitors with myriad images of themselves. While Forkner continued his experiments, the artist set about designing an expansive optical environment for Expo '70 visitors to experience. Initially imagined as a spiral-shaped room, audiences would encounter "real image" displays of familiar objects that would seem to materialize into thin air in front of them. To complicate matters further, Whitman wanted these displays to have a "zoom" feature, such that the real images initially appeared far away but then rushed toward the spectator before appearing to pass by.

At this point, Forkner found himself "overwhelmed by the extent of Bob's vision." He was also "more than a little worried" about its cost, which his managers estimated to be well over $50,000.[26] In June 1969, with the shipping date for Whitman's installation only some six months away, Tuchman, Whitman, and Forkner met with the head of Aeronutronic, to secure additional support. Although Tuchman brought along Richard Feynman, thinking the Nobel Laureate might bolster their case, Forkner's boss refused to allocate any more money to the project. Forkner continued to investigate alternatives while Tuchman corralled additional funds from LACMA. Whitman, now working from New York, redesigned his original spiral-shaped room into a more open semicircular space that could better accommodate the crowds everyone expected. In it, visitors would encounter large spherical mirrors that would produce the real images Whitman wanted as well as a wall tiled with Forkner's corner reflectors. With the basic layout now set, the main challenge—at this point, Forkner was handling almost all of the hands-on work—was manufacturing the spherical mirrors, each of them about five by seven feet in size, to exacting optical specifications.

Eager to avoid the expense of polishing glass mirrors, Forkner considered using Mylar stretched like a painter's canvas over a wooden frame and formed into the desired shape by applying a partial vacuum. But as he studied the physics more closely, the engineer realized that he could achieve the same optical effect using two *cylindrical* mirrors instead of one (harder-to-fabricate) *spherical* mirror. These could be angled open like waffle irons to create the real images Whitman's concept called for. With Philco-Ford's managers now restricting the time he could devote to the project, Forkner tried subcontracting the mirror fabrication to a display company in New York. But when he visited the company, he saw that their prototype was "disastrous . . . I couldn't find anything even vaguely resembling an image."[27]

By this point it was November and Forkner, running out of options, was starting to feel desperate. Experimenting with a handmade, half-scale model he had built, Forkner was finally able to show some progress to Tuchman and his LACMA colleagues. Encouraged by the success, Forkner now had about a month to make five sets of mirrors, each twice as large as his model. The bad experience with the New York company left Forkner convinced that the fabrication process needed close oversight. At this point, sensing an opportunity to put E.A.T.'s focus on process into play, Forkner proposed a radical solution: rather than hiring an industrial firm to fabricate the mirrors, he would use volunteers from his church. Soon dozens of helpers from the Laguna Beach Unitarian Church Fellowship were contributing fourteen-hour days, seven days a week, to the LACMA project.[28]

For more than a month, the volunteers worked out of a defunct restaurant space in Laguna Beach where they were supervised by Forkner and two other engineers from the church. Media coverage attracted "housewives, artists, children, oldsters, engineers, house painters, hippies, and the local narc," who together built mirror frames with a rib assembly curved to the right dimensions. To make the surfaces (they had a 1/500-inch tolerance) that would properly support the reflective Mylar, the volunteers first tried sanding them by hand. Signs reading "Sanding Improves Your Rhythm" and "Sanding Brings Good Karma" boosted morale. When this method proved too slow, a local machinist built an automatic sanding machine.

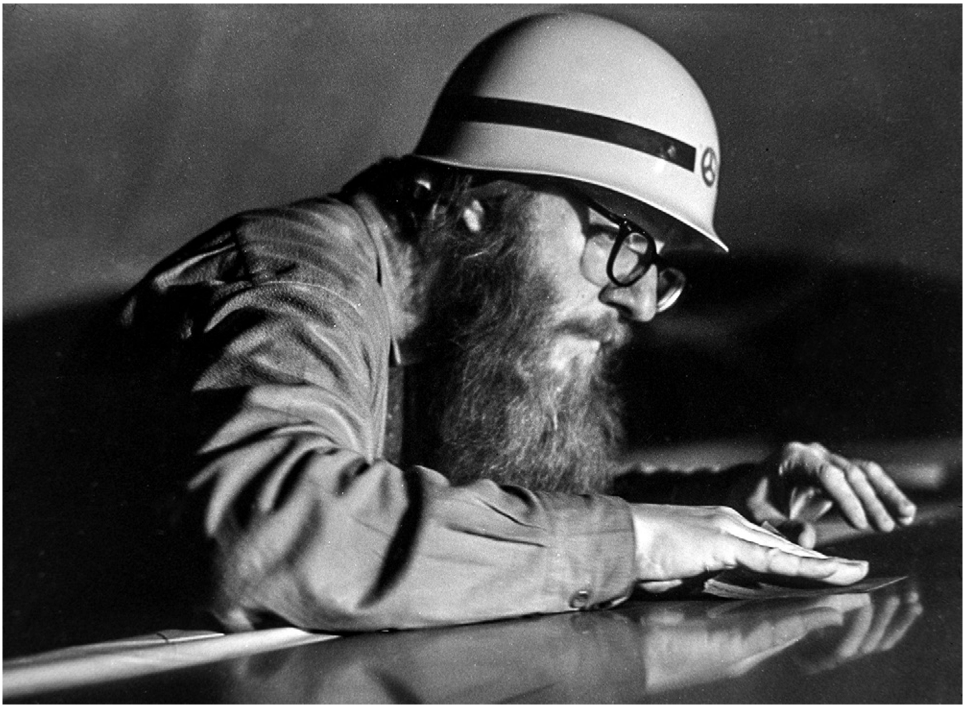

Figure 8.3 John Forkner, working on Robert Whitman and Philco-Ford Corporation's installment of *Optical Environment* at Expo '70 in Osaka, Japan. Note the peace sign on his hard hat. Photo by Tami Komai, courtesy the LACMA archives.

"I felt like Rube Goldberg, my childhood hero," Forkner exclaimed, "the sanding millstone was off our necks."

Forkner's volunteers completed the mirrors in early February. When asked what motivated the volunteers, he explained that his friends "sensed the intrinsic value of the project, primarily the value of process" and wanted the opportunity, in the context of the Apollo landings, to likewise "participate in something glorious."[29] On each Osaka-bound crate they stenciled, "To our Japanese brothers with love." A few weeks later, Forkner, granted an extended leave of absence from Philco-Ford, unpacked his team's handiwork in Osaka and started the installation process. Whitman, caught up in E.A.T.'s work for the Pepsi Pavilion, "depended completely" on his engineer friend to execute the piece, often leaving on-the-ground design choices to him.[30]

Even more than Krebs's piece, the Whitman-Forkner installation, with its reliance on optical illusions, is challenging to capture in photos. Imagine entering a darkened room. When standing under one of many ceiling lamps Forkner had installed, panels covered with the corner reflectors produced a thousand images of your face. As you looked up and moved about the room, the cylindrical mirrors made by the Laguna Beach volunteers projected ghostly images of objects—a clock, an electric drill, a cabbage, a tank of live goldfish—which seemed to materialize out of nowhere. Gail Scott, one of Tuchman's LACMA colleagues, described the whole experience as a "mysterious visual disorientation." "To see one thousand images of one's own face," she wrote, "is itself startling. But coupled with the evanescent appearance and disappearance of strangely hovering objects, the experience becomes even more extraordinary."[31]

While in Osaka, Forkner was interviewed by art critic Barbara Rose and *New Yorker* writer Calvin Tomkins. Tomkins noticed how many of the artists and engineers (including Forkner), working on the Pepsi Pavilion and the New Arts section for the US Pavilion, had formed a larger creative community, mingling freely at booze-fueled parties at the end of very long days. The engineer confessed to Tomkins that he hoped to quit his job at Philco-Ford and work for E.A.T. instead.[32] Art and technology, he told Rose, had "totally transformed" his life "in every possible sense." Forkner compared working with artists to his experiences at Esalen, a new age retreat in Big Sur, California. "One thing flowed into another. It has opened and expanded horizons for me," he said, "my own aesthetic thing expanded." Rose pressed Forkner on the different ideals of artists and engineers. "I learned about the value of art and the tremendous honesty that's required to be an artist," he said, "which unfortunately isn't true in the engineering industry." Reflecting on the larger question of collaboration, Forkner saw parallels to the teamwork required by the space program. Artists, he concluded, were starting to be aware of the power of collaboration. "Wow!" he told Rose, "you really have the beginnings of a revolution there."[33]

Maurice Tuchman joined the scores of other art-and-technology participants in Osaka along with more than forty tons of artists' gear packed into some eighty shipping crates. Acting like the supervisor of a Big Science project, Tuchman ended up staying in Japan for ten weeks, monitoring and managing the combined efforts of artists and designers, as well as hundreds of Japanese workers. "Never before," wrote one supportive art critic, "has a curator acted more as an impresario."[34]

The United States opened its official pavilion to the public on March 15, 1970. Over the next six months, more than sixteen million people tolerated long lines to see lunar rocks, sports memorabilia, folk art, and a display of modern photography.

The US Pavilion's carefully worded bilingual program described Tuchman's New Arts section as a "pioneer experiment in which industrial corporations sheltered artists in residence" while giving them the opportunity to "transmute" advanced technology into art. While each of the artists was named, visitors were told nothing about the engineers who made the works possible.

Throughout Expo '70, USIA, ever sensitive to the public relations value of their work, monitored American and Japanese newspapers for mentions of the US Pavilion.[35] Much of the "almost embarrassingly laudatory" press coverage was devoted to stories about the fist-size moon rock on display and the public appearance of the Apollo 12 astronauts. In comparison, the New Arts exhibition received relatively little attention, except in the *Los Angeles Times* (unsurprising given Missy Chandler's support for the Art and Technology Program). Henry Seldis, for instance, compared the artists to "moon explorers," venturing into the unknown to create art "teetering on the edge of tomorrow."[36] Again, the press coverage largely ignored their engineer collaborators.

After Expo '70 ended, USIA's staff prepared a lengthy report assessing their effort's successes and shortcomings. Jack Masey and his colleagues saw the collaborative artworks included in the New Arts area favorably, providing a balance to more conventional displays in Osaka of eighteenth- and nineteenth-century paintings loaned by the Metropolitan Museum of Art. Probably the "most successful and amusing object" was Claes Oldenburg's *Giant Ice Bag*. The sixteen-foot-tall, salmon-colored, animated sculptural work heaved and twisted at the entrance to the New Arts area. However, Tony Smith's *Bat Cave*, constructed from thousands of folded cardboard shapes provided by the Container Corporation of America, left some guests "puzzled and confused." USIA's staff was especially exasperated to learn that a few visitors had taken advantage of the installation's dark recesses to relieve themselves.[37] Krebs's and Whitman's pieces were judged "reasonably effective" but they demanded "more involvement . . . than the audience had time for." However, "all the time in the world would have done little to help audiences grasp what Roy Lichtenstein's film and Andy Warhol's rain machine were all about."[38] Tuchman had consistently pitched his Art and Technology Program as an experiment and, "as is frequently the case with such experiments," USIA noted, "some succeed and others fail." A year later, when pieces from the New Arts exhibit were reassembled for display in Los Angeles, the cowboy curator's experiment, along with the artists and corporations he had corralled into it, would receive much more intense scrutiny.

FOGGY NOTIONS

In August 1967, *Physics Today*, the flagship journal of the American Institute of Physics, published a series of cartoons titled "The Cyclotron as Seen by . . ." Together, they captured the diverse perspectives of an iconic Big Science instrument, the high-energy particle accelerator. To the experimental physicist, for example, the cyclotron was shown as just a nondescript black box from which data poured. Reflecting the Cold War's political economy, to the "government funding agency," Big Science labs appeared as gated palaces to which trucks carrying heaps of money arrived only to leave empty. What really amused the magazine's readers, however, was the cyclotron as seen by the lab's director—an aloof individual watching his minions at work, his feet propped on a massive wooden desk, and a portrait of Napoleon on the office wall.[39]

Similar interpretative flexibility applied to Big Art. After years of slow growth, Pepsi was finally in a position to increase its market share in Asia.[40] Meanwhile, in the United States, the company was trying to appeal to both the conservative part of American society through its "Up with People" campaign as well as the youthful counterculture market via splashy psychedelic advertisements. So, to Pepsi executives, their pavilion was simultaneously an advertisement, a golden chance to enhance the company's global recognition, and a visual statement to attract potential new customers.[41]

Billy Klüver and the scores of engineers, technicians, workers, and artists in the United States and Japan who outfitted the pavilion saw the object of their labors quite differently. Besides being a work of art, the pavilion was an "experiment in the scientific sense." But Klüver also pitched it as "an open-ended situation . . . a living responsive environment . . . an experiment in individual experience," as well as "a field laboratory." At other times, the pavilion was a "piece of hardware" that engineers and artists would program, like a computer, to create a distinct visual, audio, and tactile experience for the hundreds of thousands of visitors Pepsi expected.[42]

In reality, the pavilion was all of these things. But this multiplicity of interpretations generated continuous friction between E.A.T. and Pepsi until an irreparable disagreement occurred. Pepsi's Alan Pottasch later blamed this on E.A.T.'s commitment to "*constant* experimentation."[43] Put simply—Pepsi wanted a product but E.A.T. was invested in the process. In retrospective analyses, the falling-out was inevitable given such divergent goals. That, however, is an ex post facto judgment. A first step to understanding why the rupture between E.A.T. and Pepsi happened requires us

Figure 8.4 The Pepsi Pavilion at night, Osaka, Japan 1970. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

to see the pavilion, first and foremost, as an experimental, multimedia laboratory designed to produce immersive, programmable environments.

Visitors' experiences started outside the pavilion. John Pearce, the project's main architect, referred to the artificial fog—"white and formless . . . alive and changing"—that enveloped the structure as a "symbolic guide" to appreciating what the pavilion was all about.[44] The artists accepted the idea of a "fog sculpture" around the pavilion quite early on in their design process. Even before they gave their pitch to Pepsi, Frosty Myers had prepared a sketch showing an abstract, hemispherical pavilion, illuminated by a searchlight and surrounded by a misty veil.[45]

While it appeared to viewers as ethereal and intangible, veiling the Pepsi Pavilion in a shroud of fog required considerable research and experimentation. This months-long effort was led by Japanese artist Fujiko Nakaya. Born in 1933 in Sapporo on the northern Japanese island of Hokkaido, she was the daughter of Ukichiro Nakaya, a Japanese physicist famous for developing techniques to make and classify artificial snow crystals (a surprisingly difficult task).[46] After finishing her bachelor's degree in art at Northwestern University in 1957, she did further studies in Paris and Madrid, focusing on painting. In 1966, she met Klüver and assisted with the *9 Evenings* performances. Soon after E.A.T. received the Pepsi commission, Klüver asked Nakaya to look into the options for enshrouding the pavilion in clouds.[47]

This challenging assignment sat at the intersection of art, environmental engineering, and basic research. The Pepsi Pavilion, although not as imposing in scale as the US Pavilion, was still big, with a surface area of some 3,300 square meters. The artificial fog would have to be sufficiently thick so as to scatter light and be visible day and night. Expo '70, meanwhile, would run from early spring through early autumn, during which the fog sculpture, as Nakaya's project became known, would have to operate in a variety of weather conditions. To better understand her artwork's location, Nakaya set up an ensemble of meteorological instruments at the Osaka site to collect baseline temperature, wind, and humidity data.[48]

Nakaya also discussed possible alternatives for generating fog with scientists in Japan. One idea they considered was using dry ice. Solid chunks of carbon dioxide mixed with water or steam could indeed make a thick mist. But Expo '70 health officials objected to the plan, claiming the massive release of carbon dioxide would attract mosquitoes to the fair. Another option was using a compound of urea—a component found in mammalian urine—but this was quickly nixed for the obvious public relations reasons. In the end, Nakaya made a decision that was both aesthetic as well as practical. Avoiding chemical methods such as smoke, she opted instead to make her fog out of pure water. This, she believed, could produce a cloud visible enough to be seen, something that would be palpable to visitors but not harmful to the environment, and which would thicken or disperse as the weather changed giving a desired element of randomness.[49]

Producing fog from pure water isn't easy. In nature, fog occurs when the temperature drops until the air is saturated with water and droplets condense. This could be made to happen by dramatically cooling the pavilion's roof. Or, fog could be made by heating water, which, when surrounded by cooler air, would condense. (This is what gives rise to fog that forms on a cold morning over a warm body of water.) But both of these approaches would require huge amounts of energy, something out of step with the emerging environmental movement (not to mention that the smoke from any oil-fueled boiler would compete with the visual effects Nakaya desired).

After several months of research, Nakaya found a third path. She could spray very tiny droplets of water into the atmosphere and produce fog. In May 1969, she received a short telegram from Billy Klüver: "Elsa [Garmire] found fogman in LA . . . claims system is cheaper and easier to handle than steam. His name is Tom Mee."[50]

Thomas R. Mee was born in 1931 and grew up in New Orleans. In between earning degrees in physics, he worked as an itinerant ski instructor and smokejumper and also did service as a naval aviator. After finishing his university work, Mee joined a laboratory operated by Cornell University, where he did experimental research on topics such as cloud seeding and eliminating aircraft contrails. Then, in 1964, Mee was lured to Southern California by a Caltech alum whose company studied weather control and air pollution issues. When Fujiko Nakaya contacted him, Mee had just started his own company, a small operation run out of his Altadena garage, which planned to make instruments for weather monitoring.[51] He had never heard of Billy Klüver or E.A.T., but Nakaya's knowledge of cloud science impressed him. Moreover, he had met her father at scientific conferences and was well aware of his pioneering research on snow.[52]

Mee was initially skeptical about whether they could generate enough fog to obscure the entire 120-foot-diameter pavilion but he agreed to explore the problem with her. Mee respected Nakaya's aesthetic preference for producing an environmental sculpture of "dense, bubbling fog . . . to walk in, to feel and smell, and disappear in."[53] Nakaya and Mee dismissed suggestions to color the fog with dyes or colored lights, deciding instead that their clouds should match the pavilion's silvery white exterior. They soon focused their attention on spraying pure water, under high pressure in copper lines, through very narrow nozzles to produce dense clouds of tiny droplets. A few months later, Nakaya and Mee set up a prototype system in his backyard. The heart of Mee's system was his design for stainless steel nozzles with openings just 1/10,000 of an inch wide. A tiny pin at the tip of each nozzle scattered the water into an ultrafine mist, creating, to Mee and Nakaya's delight, a large fog bank that partially obscured Mee's house.

Mee proposed that his small company build the full-size fog system, for about $62,000, instead of having a Japanese company manufacture it, an offer Klüver accepted.[54] In March 1970, Mee and Nakaya met in Osaka where they supervised installation of the full-scale system his company had built. Wind tunnel tests by one of Nakaya's colleagues in Kyoto, using a scale model of the pavilion, allowed them to optimize the placement of the system on the building's roof. When the fog system was fully functional, over 2,500 specially crafted nozzles could atomize some 11,000 gallons of water an hour. The pure white fog they generated roiled and spilled over the structure's irregularly angled and faceted roof and drifted out over the fairground. (A test run brought the local fire department, sirens blaring, who had interpreted the fog as smoke.) Meanwhile, a control system allowed Nakaya to tweak the density of her fog sculpture with ambient conditions varying the effect further.

Although nearby exhibitors groused about how the fog obscured their concessions and buildings, it helped entice people to the pavilion. Images of the crinkled dome, especially at night when white light from high-intensity searchlights combined with sheets of fog to create an angled square frame around the structure, were strikingly beautiful. On observing the billowing mists that E.A.T.'s research and development project had produced, one Pepsi executive reflected that the artificial fog around the pavilion made him think of the clouds "that hover near the top of Fujiyama." Artist Robert Breer, meanwhile, saw comparisons to the mist and clouds commonly found in Edo-period Japanese landscape paintings.[55] With her environmental sculpture, Nakaya managed to connect the pavilion to both the natural world as well as art history.

SILVER LININGS

When Fujiko Nakaya started working on the fog project, she made several sketches and drawings of the Pepsi Pavilion, surrounded by billowing clouds. But until she tested Mee's system in Osaka, the visual effects it would actually produce were speculative. We can think of it as analogous to a small-scale research experiment where the outcome is unknown. However, Big Science projects, with their armies of engineers, scientists, and managers, often have clear and specific goals—land a space probe on *that* planet and make *these* specific measurements, for instance. The pavilion's other signature visual feature, the enormous mirror inside the dome, more closely resembled this mission-oriented aspect of Big Science.

From E.A.T.'s earliest design meetings, the mirror assumed a central role. It was, Frosty Myers said, the "key to the whole Pavilion" and it dictated much of its interior design.[56] Experts like Klüver and Elsa Garmire could accurately predict, using physics calculations, what a guest would see when standing at various points under a ninety-foot-diameter hemispherical mirror. Therefore, the chief question leading up to the opening of Expo '70 was less about what it would look like but rather how to achieve it. Because the mirror was so central to the pavilion's overall visual experience, getting it done right was critical.

Much of the research and testing for the pavilion's mirror project was done by members of E.AT.'s Los Angeles chapter. Throughout 1969, Elsa Garmire worked closely with artists David McDermott and Ardison Phillips to investigate possible construction methods for the mirror. Initially, Garmire, backed by Klüver and Pearce, thought that only rigid panels, molded to fit the dome's interior roof and individually adjusted, could provide the necessary optical accuracy. Making prototypes of these was delegated to the Tsutsunaka Plastic Industry Company, which was affiliated with the Japanese construction firm building the pavilion's shell exterior. However, McDermott, Phillips, and a small team from UCLA connected to the school's Department of Urban Design, pursued a different and ultimately successful alternative.[57] Imagine standing inside a balloon that has its inside surface covered with reflective material. If the balloon is properly filled with air, it would make, in theory, a spherical mirror.

By the spring of 1969, the Los Angeles group had managed to build scale models of the mirror dome using this approach on a sound stage loaned to them by a movie studio. Meanwhile, Eric Saarinen, an aspiring filmmaker and son of the famous architect—his documentary about the San Francisco Exploratorium would be nominated for an Academy Award in 1975—recorded their experiments for a short film he was making about E.A.T. and the Pepsi project. (One of their prototype mirrors later made a guest appearance in the much-loathed 1970 film *Myra Breckinridge*.) In May 1969, Klüver, Robert Whitman, and engineer Fred Waldhauer visited Los Angeles to assess the chapter's work. The experience of a scale model less than one-quarter the size of the final version was somewhat underwhelming, so Klüver approved construction of a full-scale test model.

This, however, meant persuading Pepsi to commit an additional $10,000 to the project. Like all Big Science projects, maintaining fidelity to cost and schedule estimates for the pavilion's various subprojects remained a challenge. In his pitch to Pepsi, Klüver explained his group needed to "get experience with the environment created inside the mirror dome," but also noted the "great P.R. value" the company would accrue with journalists who might not be able to visit the pavilion in person when it opened in Japan.[58] Pepsi's accountants acquiesced.

Many of the technologies that E.A.T deployed in the pavilion—indeed, those underpinning the entire art-and-technology movement—were derived in some way from Cold War-era defense research. The mirror dome was no exception. Bell Labs, Klüver's former employer, had closely worked with NASA on Project Echo to build "balloon satellites," one hundred feet or more in diameter, that could reflect telephone, radio, and television signals from space. Calvin Tomkins, in fact, had described Project Echo in a *New Yorker* essay featuring John Pierce, Klüver's boss, as the protagonist.[59]

G. T. Schjeldahl Company, based in Minnesota, had built the Echo satellites for NASA. Like scores of other firms, G. T. Schjeldahl was tightly bound to the needs of military and aerospace projects. Besides making high-performance balloons for space and atmospheric research, the company also built waterproof barriers for the navy's Polaris missile programs. For its balloons, Schjeldahl's engineers perfected their ability to combine elliptical sections (called "gores") of thin, lightweight polymer films into strong, inflatable structures. In 1966, the company again demonstrated its expertise when it built the Passive Geodetic Earth Orbiting Satellite (PAGEOS) for NASA. The one-hundred-foot-diameter inflatable spacecraft weighed just 125 pounds. Measurements made once PAGEOS was in orbit helped researchers better understand the earth's shape and gravitational fields, two seemingly mundane properties valuable for, among other things, improving the accuracy of intercontinental ballistic missiles.

Klüver saw the parallel between these large inflatable satellites and the giant mirror dome E.A.T. wanted to build. In fact, the visual experience of the Pepsi dome was essentially what one would see from *inside* something like an Echo satellite. Unfortunately, NASA managers told Klüver they didn't have a spare balloon satellite to donate.[60] In May 1969, Klüver flew to Minneapolis to meet with engineers at G. T. Schjeldahl. (It is a pleasing irony that the son of the company's founder, Peter Schjeldahl, would become a prominent art critic.) One of the people he encountered there was Sigvard Stenlund, a project engineer with a physics degree. Stenlund—"tall, crew-cut . . . reserved . . . a real Midwesterner"—recalled being initially "appalled" by the artists' appearances. But, after spending some time with them, he decided that "while they might look like hippies," they were both technically capable and dedicated to the project.[61] G. T. Schjeldahl's cost estimate to make a demonstration model for E.A.T. was initially seen as too high but Klüver kept in touch with Stenlund who was increasingly curious about the art-technology nexus. Months later, when his managers ordered him to quit the Pepsi project in favor of a more lucrative NASA contract, Stenlund refused and joined E.A.T.'s staff in Osaka.

When a new telescope is used for the first time, the occasion is called "first light." On September 30, 1969, something similar happened inside a capacious dirigible hangar at a Marine Corps airbase in Santa Ana, California. That evening, E.A.T.'s staff unveiled a full-size model of the mirror dome to Pepsi executives, art writers, and other Southern Californians associated with the region's art-and-technology projects. The ninety-foot dome produced visual effects that matched Elsa Garmire's earlier calculations. As she later wrote, the mirror dome offered spectators "an infinity of private worlds . . . [where] illusion merges with reality," as what a person saw depended on ambient lighting and where they were standing inside the dome.[62] These variable effects meshed with E.A.T.'s goal of providing each pavilion visitor a personalized, interactive, and immersive experience.

Gene Youngblood, a columnist for the *Los Angeles Free Press*, a local underground newspaper, found himself mesmerized when he ventured inside E.A.T.'s "giant womb-mirror" for the first time. "I've never seen anything so spectacular, so transcendentally surrealistic. . . . The effect is mind-shattering," he wrote, "incredible phantasmagorias of color and light whirl insanely about the entire environment." Recalling the recent Apollo 11 moon landing, Youngblood's vision led him to conclude that "we've escaped the boundaries of earth and again have entered an open empire in which all manner of mysteries are possible."[63]

Alan Pottasch's thoughts as he mingled with E.A.T. members and curious Marines inside the dome were more down to earth. As Eric Saarinen filmed dizzying images of artists and engineers playfully experimenting "with the possibilities of non-ordinary human perception," the executive remarked how his company was committed to paying attention to the fact that "artists and engineers are trying to say something."[64] One suspects that Pottasch, if pressed, might have had a hard time articulating exactly what this meant. Meanwhile, Pepsi's leadership continued to worry about E.A.T.'s loose adherence to budget and schedule projections.

Despite the technical success E.A.T.'s team in Los Angeles had with the inflatable mirror, the rigid mirror option still appeared to Klüver and John Pearce as the safer option. The deadlock wasn't resolved until the debut of Expo '70 was just a few months away. Klüver, Pearce, and Stenlund made a hurried trip to Osaka where they learned that the Japanese company contracted to make rigid mirror panels would not guarantee their optical quality.[65] Klüver finally placed his bet with Stenlund's employer.

Rather than inflating the mirror dome from the inside, Stenlund opted to use "negative" air pressure to create a rigid reflective surface. An airtight wooden shell, slightly larger than the balloon itself, contained the dome's plastic reflective material. When air between the shell and balloon was pumped out, the ambient air pressure inside the dome would expand it to the desired size. This design choice also eliminated the need for complex air locks at the pavilion's entrance and exit points. Soon, G. T. Schjeldahl was on its way to delivering E.A.T.'s hemispherical mirror. But, when E.A.T. first pitched Pepsi its proposal, Klüver and his colleagues guessed the mirror would cost about $60,000. By the time Expo '70 opened, fabrication costs and other expenses meant that giving the cloud-covered pavilion a silver lining would require almost $250,000.[66] Doing Big Art, like Big Science, demanded big money.

FAIR FRICTION

As historians well know, there are many hazards on which Big Science projects can founder. Researchers' goals, technological capabilities, budgetary limits, and schedule demands must be harmonized. As projects became bigger and more complex, there is also a need for the rational organization of technical expertise. James Webb, NASA's head during the Apollo heyday, called this "space age management"—"the ability to organize the complex and do the unusual."[67] For Klüver, the pavilion had become as much a challenging experiment in organization as it was about art and technology. There were, Klüver told Calvin Tomkins in an Osaka taxi, a related set of "hardware problems" and "software problems." The real work—where Klüver wanted E.A.T. to excel—was at the interface between them where both could be solved.[68]

By 1970, E.A.T. was overseeing a global network of artists, engineers, technicians, and contractors. Although cartoon depictions of Big Science lab directors might show them relaxing in wood paneled offices, Klüver's travel schedule tells a different story: more than a dozen overseas trips to Japan, India, and other destinations in 1969 alone. Then there were weekly trips from New York to Washington, Boston, and Los Angeles to maintain momentum (and funding) for E.A.T.[69] His regular outfit in Osaka was a "worn suede jacket and a nondescript fur hat." Somewhere along the way his front tooth fell out, a defect he took no time to remedy despite appointments Fujiko Nakaya arranged with Japanese dentists.[70] Today, stacks of hefty archival boxes—filled with thousands of pages of telex transmissions sent at every hour of the day and across multiple time zones, along with reams of spreadsheets, progress reports, and contracts—affirm the magnitude of the management task facing Klüver and his colleagues. Increasingly frustrated with Pepsi's stubbornness when it came to reimbursing E.A.T., Klüver twice threatened to pull out of the project, tactics which persuaded the soft drink company that an expensive pavilion was better than the embarrassment of having none at all.[71]

E.A.T.'s "casual accounting methods" coupled with turnover among Pepsi's management generated more confusion.[72] Contracts took months to receive final approval, while in the meantime, costs continued to rise. By late 1969, E.A.T.'s initial estimate of $859,000 had grown to almost $1.3 million as Pepsi's Pottasch verbally committed tens of thousands of dollars extra to pay for artists' live programming inside the pavilion once Expo '70 began.[73] Including the construction of the dome itself, Pepsi was on track to spend about $2.5 million—almost a third of the entire National Endowment for the Art's budget for 1970—for Expo '70. "The Pepsi Pavilion is the largest single most complex and difficult Work of Art produced in our time," Klüver reminded his colleagues, while "Pepsi is now the single largest Patron of the Arts."[74]

E.A.T.'s intent from the outset was to create an integrated and immersive environment. Critic Barbara Rose, who spent several days in Osaka talking with E.A.T. members, christened their project a "total work of art"—a *Gesamtkunstwerk*—in which the aesthetic and technological, the human and organic, the mechanical and electric, were all united.[75] If you visited the pavilion, you would, of course, notice the billowing, shifting fog surrounding the faceted white dome, lit and framed at night by four high-intensity xenon lights. Near the entrance, you would find seven, white, person-size floats made by artist Robert Breer with help from Klüver's engineers. These slowly moved about autonomously, making soft sounds—talking, music, sawing wood—only to gently reverse direction when they bumped into something. At the slanted entrance tunnel, a Japanese greeter wearing a futuristic-looking red dress and bell-shaped hat would hand you a clear plastic wireless handset. The tunnel lead you to a darkened antechamber, named the Clam Room for its rounded shape.

As you moved from this transition space up to the main Dome Room, you would be showered with constantly changing red, green, yellow, and blue light patterns from a krypton laser. This system, which created what Barbara Rose called an "electric Pollock," had largely been put together by Lowell Cross, an electronic musician who worked with David Tudor, and Carson Jeffries, a physicist from Berkeley. Once inside the giant mirrored dome, you would see images of people and objects floating in space upside down above you. The interior light system was designed by Anthony Martin, who had done similar work at the Electric Circus, and could be controlled manually or automatically via paper punch tapes.

Besides playing with visual perception, the dome also confounded people's sense of acoustic reality as echoes and reverberations created auditory illusions. There was a tactile aspect as well because the whole room sloped gently upward to the center where a glass insert in the floor allowed you to see the entrance tunnel with its laser lights. The pavilion's designers divided the interior floor into eleven sections, each with its own materials and texture. While standing on the plastic grass, for

Figure 8.5 Greeter at the Pepsi Pavilion, with an audio handset for visitors. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

Figure 8.6 Performance inside the Pepsi Pavilion; note the images floating above performers. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

example, antennae embedded in the floor might make your handset play the sound of birds chirping or a lawn mower. Throughout the whole time, you were free to wander about at your own pace, in any direction, and compose your own sensory experience.[76]

While the pavilion offered a cohesive visual, audio, and tactile experience, like a space probe, it relied on the integration of several discrete subsystems. While the fog and mirror were the pavilion's most obvious visual effects, hidden away in a control room and above visitors' heads, technologists had installed an elaborate sound system. Like many other Big Science initiatives, it had been substantially "de-scoped," as project managers say, over time. When David Tudor first discussed the sound system with Larry Owens, a young engineer taking a leave of absence from Bell Labs, he envisioned it having twenty separate audio channels that would send sounds and music through sixty speakers placed in the dome's ceiling. By the time the pavilion opened, this was downsized to just eight channels projected through thirty-seven speakers. Nonetheless, Owens and Tudor, working with experimental composer Gordon Mumma and engineers John Pan and Fred Waldhauer, designed a sophisticated ensemble of equipment that was second only to the mirror dome itself in cost.

When it was finished, the pavilion's sound system accepted signal inputs from up to thirty-two different sources, which programmers could then modify, amplify, and toggle between the speakers. The output projected into the dome could include "line sounds" that bounced rapidly between speakers, "point sounds" heard from a single speaker, or "immersive sounds," which appeared to come from all directions. Staff could control all the sounds and lights inside the pavilion via a central console in real time or run audio "programs" stored on punch cards. Owens, working with Bell engineer Per Biorn, designed a "Master Programmer," an electronic machine with output controlled by punched paper tape, and linked it to the pavilion's sound and light system. To this they added a closed-circuit television feed and crowd-counting system that surveilled the flow of people in and out of the pavilion. The result was a closed and computer-enabled information system that could monitor, control, and create an electronic environment of visual and audio signals.[77]

The pavilion's multimedia environment, like natural ones, was responsive and changeable. Initially, the plan—one which Pepsi favored—was for E.A.T. to develop automated multimedia programs, like computer software, that the pavilion would "run" as guests came and went. However, as Klüver and his colleagues came to appreciate the near-infinite range of possibilities that the pavilion's sound and lighting systems offered, a new idea took hold.

Figure 8.7 David Tudor (right) and Ritty Burchfield in a moment of creative exasperation at a control panel for the pavilion's sound system. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

Big Science labs often operate their particle accelerators and giant telescopes as user facilities. Scientists submit a proposal for a project and, if selected, they are given time to use the instrument and carry out their research. In June 1969, E.A.T. proposed something similar: a "live programming" initiative for the pavilion. "Resident programmers," selected from a pool of applicants, would spend several weeks in Osaka exploring the pavilion's potential as an artistic instrument. While receiving $500 a week, programmers would have access to a library of several hundred "natural environmental sounds" as well as longer recordings that David Tudor had prepared. E.A.T. was quite open to the live programming's content with a few caveats. As they told potential applicants, "experiences that tend toward the real rather than the philosophical" were encouraged. Somewhat oddly, given the tumultuous politics of

Figure 8.8 Children at Expo '70, having their own experience in front of the pavilion, exploring Robert Breer's cybernetic floats. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

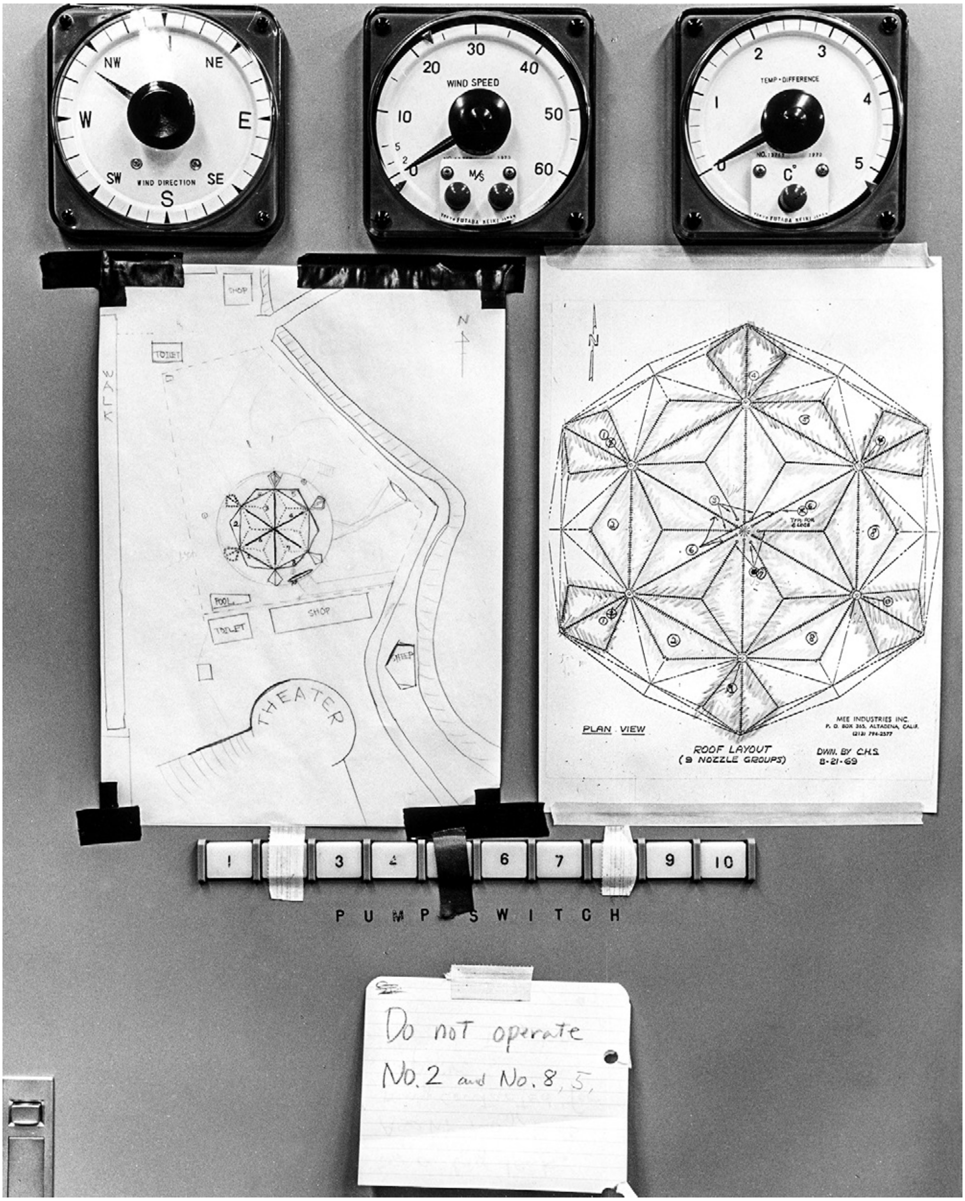

Figure 8.9 Control panel for the pavilion's fog system that Fujiko Nakaya and Thomas Mee designed. Note the division of the pavilion into zones, suggesting the degree of control Nakaya had over the visual effects their system could create. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

the time (but perhaps in keeping with the conservative nature of its patron), E.A.T. specified it was "not interested in political or social comment."[78]

E.A.T. hoped to receive applications from "artists, musicians, poets," as well as "engineers, scientists, sportsmen, [and] toy designers."[79] Eager to generate publicity, E.A.T. proposed adding special programs that might include "well-known personalities" like Sidney Poitier, Andy Warhol, and Allen Ginsberg along with soliciting contributions from American labor organizations. Pottasch had a different aesthetic. He suggested Pepsi include an "American Indian in full costume" doing a rain dance or a "cowboy rope artist."[80] Pottasch also asked E.A.T. to create programs especially for children, describing in one memo a multimedia version of Little Red Riding Hood. Although open to Japanese folk tales (such as Momotarō, a young boy born from a giant peach who fights a band of demons), he wanted it to entice visitors to "sing along."[81] The archive doesn't preserve Klüver's response to this idea.

E.A.T. planned to host some twenty-four different programmers from the United States and Japan during the six months of Expo '70. Multimedia artist Red Grooms, for instance, offered to "do a Wild West show" using double-life-size puppets that he and his collaborators would make in Japan. Fluxus composer Takehisa Kosugi proposed accompanying a simulated solar eclipse with original electronic sounds. Also included among the ideas E.A.T. selected was John Forkner's proposal for "Programming the Pavilion Dome as a Giant Light Machine." The engineer imagined a cybernetic environment in which the combined movement of performers and audience members would control optical and sound effects in the Mirror Dome.[82]

The opening of a new Big Science facility is usually accompanied by speeches, press briefings, and a lavish dedication. The Pepsi Pavilion's debut was no different. About a month before the pavilion and Expo '70 opened to the public, members of the E.A.T. team, many accompanied by their families, started arriving in Osaka. The winter weather, with cold rain sometimes turning to snow, made working in the unheated pavilion uncomfortable. Calvin Tomkins's diary notes, which he later refined into a fifty-page *New Yorker* feature, captured the escalating chaos, confusion, and tension as four dozen artists, engineers, and technicians worked double shifts to install, test, and troubleshoot the pavilion's various systems.

Tomkins also observed the rising tension between E.A.T. and Pepsi as the pavilion's opening combined the technical demands of a research experiment with the nonnegotiable deadline of a Broadway show's opening night. Pottasch, who seemed at times to be the only person at Pepsi overseeing the project, acknowledged that his company's biggest mistake "was not realizing the entire project was experimental."

"Billy is a complete mystery to me to this day," he told Tomkins, "I've lost more sleep over this project than I have over anything else in my life."[83]

By the time Pepsi and E.A.T. held their press preview on March 11, 1970, everything was more or less working at the pavilion. The "fog pouring off nicely against momentary blue sky and fluffy clouds" transformed it into the "only soft spot at the fair." Inside, Pepsi's public relations officer for Japan fretted that "common people don't understand art. I tell them it means nothing, right?" Art critic John Canaday "appears and leaves. Pepsi types not saying dick to anyone." Tomkins wandered over to inspect Tuchman's New Arts exhibit and judged the installations by Krebs and Whitman-Forkner "marvelous." Once the "Pepsi types" left, imported tequila and Suntory whiskey flowed "like water" as E.A.T. staff blew off steam.[84]

The next day, high-level Japanese and American executives from Pepsi arrived for the pavilion's official dedication. Donald M. Kendall, president of PepsiCo and a confidant of Richard Nixon, took a break from high-level trade negotiations to visit. His positive reaction on seeing what his company had paid for momentarily buoyed the spirits of many E.A.T. members. Takako Shimazu, the daughter of Japan's Emperor Hirohito (she was formerly known as Princess Suga), and a "phalanx of photographers" joined the Pepsi delegation and the whole group entered the Clam Room, passed through the laser shower, and climbed into the Mirror Dome. After a brief Shinto ceremony, Shimazu cut a ribbon tethering a large red balloon to a ceremonial altar. Sounds of thunder from the pavilion's speakers filled the Mirror Dome as the balloon floated upward, meeting its illusory image on the way. Outside the pavilion, technicians worked in the snow to fine-tune Breer's creeping floats. Everyone was "cold, wet, exhausted, and happy," Tomkins recorded, "Billy smiling his Buddha smile."[85]

Building a Big Science facility is one thing. Running it presents another challenge and often a costly one. For example, astronomers generally assume that annual operations costs for a large observatory will be somewhere around 5 to 10 percent of the facility's initial construction cost. Researchers have learned the hard way that even when a Big Science facility is built, its survival isn't assured. These facts of doing Big Science had parallels as well in the pavilion's denouement.

As tens of thousands of Expo '70 visitors received their personal aesthetic experience at the pavilion, E.A.T.'s staff observed the daily wear and tear their creation received with mounting concern. Maintaining the pavilion was going to take time and money. Moreover, while E.A.T. had installed most of the pavilion's "hardware," questions about its "software"—the live programming—remained unresolved.

Pottasch asked Klüver for a new operating budget that would accurately reflect the cost of the live performances. E.A.T.'s president projected this might run upward of $400,000. Klüver's estimate, on top of what Pepsi had already spent, pushed the executive past the limits of his patience. Just a month after the pavilion opened to the public, Pepsi's attorneys informed E.A.T. that the group's services were no longer needed and they were unceremoniously expelled.

What followed was its own form of absurd performance art. Klüver hastily returned to Japan to try and salvage the situation. Klüver's thoughts, written on the plane, give a sense of his state of mind: "Few people can deal effectively in a high-pressure confused situation. Yet it is the situation in which the artist creates and in which scientific discoveries are made. . . . We must accept the experiment, the trial, trust people, accept failure. . . . Fuck-ups will occur. . . . During this project this question of responsibility was never really understood—and I question at this point if it ever could be in a project like this."[86]

In Japan, Klüver learned that Pottasch was trying to selectively employ key E.A.T. members at double their salary. Once formally evicted, E.A.T. staff in Osaka had removed—or, as Pepsi claimed, stole—the pavilion's audio programming tapes. This act of smuggling impelled Pepsi to fill its avant-garde pavilion with recorded music of marching bands and trite song selections like "It's a Small World." Pepsi's "crude methods" were all the more wounding as the pavilion's experimentation at the interface between hardware and software was finally starting to work smoothly.[87] The Japanese artists E.A.T. had chosen to contribute to the pavilion's live programming were especially disappointed by Pepsi's decision and rumors floated about that Japanese student activists might protest. Pepsi and E.A.T. were, Tomkins jotted in his diary, "sitting in a very inflammable forest" together. Meanwhile, E.A.T.'s huge financial debts placed the organization's survival in doubt. The situation wasn't resolved until Theodore Kheel, the group's patron and promoter, mediated a settlement between E.A.T. and Pepsi.[88]

When a large-scale science experiment concludes, researchers typically spend months or years poring over the data it generated while planning with engineers and patrons to design the next, usually more ambitious, iteration. This process of securing funding, finalizing designs, enlisting partners, and building equipment can take years, sometimes decades, before the next experiment starts. In the gap between conception and execution, changing economic, political, and social circumstances can destabilize the rationale and resources for the mission. Physicists proposed the Superconducting Super Collider in the 1970s, for example, when appeals to international prestige and beating the Soviets carried considerable weight. But, after 1990, those Cold War justifications evaporated and the megaproject was soon cancelled.

Expo ’70 represented the debut of Big Art on a grand, international scale and now the first experiments were over. Ideas and proposals for LACMA’s Art and Technology Program and the Pepsi Pavilion had germinated for years before the initial results were unveiled in Osaka. As the new decade began, artists and engineers, along with the museums, galleries, and corporations central to their work faced a changed environment. Meanwhile art enthusiasts and critics alike were starting to view the once-hyped merger of art, technology, and industry in a new light.

9

AMPLITUDES

> Particularly among groups who have defined their "art" more or less in terms of technological innovation, this turn away from the Enlightenment notion of the aesthetic as the "disinterested play of the senses" can sometimes provide the material basis for establishing sustainable linkages with highly charged sectors of the global economy.[1]
>
> Michael Century, 1999

In November 1969, Otto Piene gave a seminar at MIT's Center for Advanced Visual Studies (CAVS). Piene, a German artist recruited by Gyorgy Kepes, had long experimented with various technologies, including large-scale light displays and inflatable sculptures. After his talk, Piene discovered a mimeographed pamphlet left behind by members of the so-called Council for Conscious Existence. With crudely inked illustrations and dense, Marxist prose, it critiqued CAVS's goal of bringing artists and technologists together with withering vulgarities. Piene, it claimed, was no artist but rather a "WHORE for power" devoted to "decorating the society of consumption." Another artist affiliated with CAVS was branded a "syphilis . . . a plague eating into consciousness." The lacerating diatribe concluded, "And to you, Gyorgy Kepes, whose dream it was to gather this scum, fuck you."[2]

Fast-forward to 1985. Ronald Reagan has been inaugurated to a second term after campaigning on an optimistic theme of "Morning in America." After years of increased tension, the Cold War was beginning to lurch to a halt. On MIT's campus, construction crews were finishing a sleek new "arts and media technology" building, with donations from major American and Japanese companies covering much of its $45 million cost. Dedicated later that year, it became the home of MIT's glitzy new Media Laboratory. As the "greed is good" sensibility of the 1980s morphed into the dot-com era's obsession with disruption and creative destruction, writers depicted the Media Lab as a profitable fusion of art, design, and technology built on a foundation of "new media" technologies.

Designed by MIT alum I. M. Pei and standing as "slick as a corporate logo," the building also included a traditional art gallery. However, Nicholas Negroponte, a professor of architecture at the school, drew a clear distinction between the new venture and CAVS, now almost two decades old. "This is not an advanced art school," the Media Lab's director pointedly stated. Rather, Negroponte pronounced the Media Lab as *the* place where creative individuals working across disciplinary cultures would be "inventing the future."[3] The timing was right and his sales pitch worked. Corporate sponsorship raised the Media Lab's annual budget to some $25 million and scores of MIT students swarmed into its workshops and classrooms. The Media Lab soon acquired a reputation as a place where one could do engineering, express oneself artistically, and perhaps also get rich.

These two vignettes, centered around the same institution, provide a pair of bookends that mark the ebb of one wave of art-and-technology activity and then, fifteen years later, the surge of a new one. Although few people have heard of the Council for Conscious Existence, its condemnation of CAVS foreshadowed a wave of disapproval from artists, art critics, and even a few engineers toward the art-and-technology movement that emerged in the 1960s. To be clear, these critiques didn't *cause* the waning of interest among artists and engineers. Critical judgments and stylistic shifts coincided with and were eclipsed by broader social and economic changes that effectively triggered the art-and-technology movement's seemingly sudden retreat. In March 1970, protestors from the Art Workers Coalition picketed Automation House, claiming E.A.T. was devoted only to presenting the "baubles of capitalism." By year's end, Billy Klüver pronounced that his group's efforts to meld art, technology, and industry were dead.[4] In Paris, Frank Malina was less hasty to declare defeat but eventually he too wondered if "perhaps interest in art, science, and technology has passed its little peak."[5] And, at MIT, Otto Piene, who became the new director of CAVS in 1974, wondered, "How, then, is the much-yahooed copulation of artists, scientists, and engineers working at all?"[6]

The first art-and-technology wave had been closely aligned with tools and technologies from the Cold War's military-industrial complex. The next wave of art and technology surged more strongly, however, with support from the entertainment and information industries. Concerns about economic competitiveness amid post-Cold War uncertainty modulated this wave. New tools, such as user-friendly personal computers, digital cameras, and the internet, helped make it possible. Corporate “studio labs” in new regions such as California’s Silicon Valley provided well-equipped spaces where technologists, artists, and designers could connect and collaborate.[7] These successive waves of art and technology, rising and falling in all sorts of diverse manifestations, left behind ripples and reverberations that are still with us today.

ART OUT OF ORDER

In her book *The White Album*, Joan Didion claimed that the sixties finally ended for her around 1971, when she abandoned Hollywood in an effort to escape the bad vibes gusting through Southern California. The art-and-technology movement reached a fevered climax that same year when Maurice Tuchman presented the results of his Art and Technology Program to museum goers in Los Angeles. If the glitzy events that Experiments in Art and Technology had organized in New York represented an optimistic, Woodstock-like moment for art and technology, Tuchman’s exhibition was its Altamont.[8]

A backlash against art and technology had been building for some time with artists and art writers sounding the first serious warnings. In 1969, Gyorgy Kepes was in the midst of organizing an exhibition for the tenth São Paulo Biennial. Kepes initially invited twenty-three artists to collaborate as part of the show’s official submission from the United States. Brazil, however, was controlled by a right-wing military dictatorship who had come to power in 1964 by ousting a democratically elected left-wing government. The new government systematically and sometimes violently repressed dissent from Brazil’s artists, writers, and other intellectuals.[9]

Kepes’s personal politics were left of center, he was opposed to the Vietnam War, and he had supported MIT faculty and students who announced a work stoppage in early 1969. He also still imagined that interactions between CAVS’s artists and MIT’s technologists could somehow reduce the school’s focus on military-related research. His sentiments, however, did not prevent several artists from publicly withdrawing from the São Paulo show. In the face of this setback, Kepes tried to focus on the positive aspects of collaboration while noting that he recognized “the justification of confrontation with all inhuman political power systems” (words which gave MIT administrators heartburn after the *New York Times* quoted them). In pushing to keep lines of communication open, Kepes said it was "better to light a single candle than to curse the darkness."[10] Sculptor Robert Smithson would not have it. "I am sick of 'lighting candles,'" he wrote Kepes. "As rockets go to the moon, the darkness around the earth grows deeper and darker."[11]

In the end, Kepes did manage to organize an exhibition. "Explorations," the first collaborative effort by CAVS artists, opened in 1970, but in Washington, DC, not Brazil. Critics' evaluations ranged from ho-hum to hostile. Although Grace Glueck appreciated Wen-Ying Tsai's cybernetic sculptures, she found that "some of today's zappy, technologically-oriented art" might soon "seem as hackneyed" as the paintings that had once graced nineteenth-century European salons. "It really takes a lot of art," she observed, "to make technology esthetic." At the *Nation*, critic Lawrence Alloway traced Kepes's ambitions back to the prewar Bauhaus ideal in which "industrial society is supposed to find its true image." But instead of "cultural lodestones," Alloway instead saw a "frivolous and gross fantasy" oriented around an "art of mostly trivial *effects*."[12] Nonetheless, the steady flow of visitors to the show suggested that art-and-technology shows remained popular among the masses even if they polarized the art world cognoscenti.

Despite mounting opposition, Jack Burnham, Kepes's CAVS colleague, was planning an even more ambitious undertaking called "Software." With considerable funding—estimates ran as high as $125,000—from American Motors and other corporations, Burnham planned the exhibition as a continuation of his art-as-systems idea. Describing previous "machine art" as more focused on "hardware" (i.e., actual devices), Burnham set out to "remove the traditional props of art," which were merely the "vestiges of painting and sculpture."[13] He wanted "Software," which opened at the Jewish Museum in New York in September 1970, to help people see technology as a "pervasive environment altering our consciousness vastly more than art."[14] Burnham intended the devices on display to serve as "transducers" relaying information to spectators, which would go beyond the expectations associated with seeing and appreciating things. By removing divisions between art and non-art, "Software" would—here we see lingering shades of C. P. Snow—also dissolve "distinctions between the artistic and technical subcultures."[15]

"Software" was organized as a technically complex undertaking that relied heavily on cutting-edge computer hardware. But this equipment frequently failed to work properly. As a result, many of the pieces in "Software" were accompanied by a "Temporarily Out Of Service" sign. The end result was a "capricious and sometimes

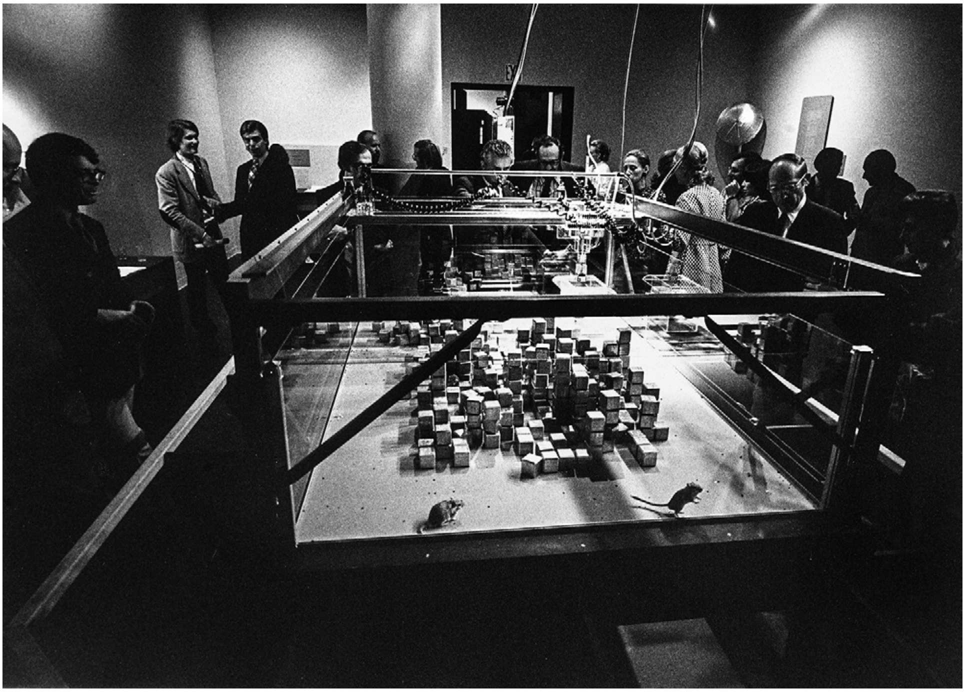

Figure 9.1 Spectators observing the activity inside *SEEK* at the 1970 "Software" show at the Jewish Museum. MIT's Nicholas Negroponte, who later founded the Media Lab, is visible to the left in the background, in the black suit. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

fascinating educational display," but a "confusing" art show.[16] One art journal editor recalled seeing gallery officials "shaking their heads sadly" at the broken equipment as they failed to understand that "the big point in Art and Technology manifestations . . . has been that none of the technology works."[17]

Ironically, for many viewers, the stars of "Software" were not computers. They were gerbils. The rodents were the prime movers in a piece called *SEEK*, created by Nicholas Negroponte and his Architecture Machine Group at MIT. Planned as an experiment in interactive environments, *SEEK* was constructed as a large table, surrounded by Plexiglas walls, with a roving computer-controlled electromagnetic hand overhead. Inside, forty gerbils ("selected for their curiosity") shared space with hundreds of two-inch polished metal cubes. As the mammals pushed the blocks around to build a three-dimensional environment, the magnet attempted to restore some semblance of order. By using gerbils as proverbial guinea pigs, Negroponte wanted to "tell architects and urban planners how humans react and adjust to a changing environment."[18] As one critic phrased it, the result was "*Gerbil ex Machina*" as the furry creatures eluded the magnet machine's controlling interventions and built nests and pathways. He went on to describe motionless gerbils staring in ennui, terror, or worse at the grappler's motionless arm, slightly coated in rodent excrement. To him, this was a warning. "Artists who become seriously engaged in technological processes [should] remember what happened to the gerbils who tried to collaborate."[19]

There was also controversy about what *wasn't* in the galleries for "Software." Artist Jean Toche, for instance, planned a piece titled *Air Pollution* but withdrew it given the sponsorship of a major auto maker. Meanwhile, a film collaboration about the show foundered over accusations of censorship—two of the filmmakers wanted to insert provocative titles such as "the system promotes software to postpone its own collapse"—and their films were cut into ribbons, evidently an act of self-sabotage.[20] The night before "Software" opened, a janitor allegedly damaged the show's main computer, prompting Jack Burnham to suspect more foul play. Finally, conceptual artist Agnes Denes publicly blasted the show's "overall incompetence," describing how she found herself "caught in the gears of a system within which shows of this type are financed and publicized with complete cynicism."[21]

By the time "Software" ended its six-week run, the technical problems and disputes had cost the Jewish Museum's director his job. Burnham, meanwhile, blamed his fellow artists for being both unrealistic in their demands and hypocritical when it came to the patrons who supported their work. Artists, he pointed out, gratefully accepted fellowships from the Guggenheim Foundation, whose fortune was secured in the nineteenth century via rapacious mining activities, but were increasingly hostile when support came from contemporary industry. The parallels to criticisms made of the supposed amoral attitudes held by engineers and scientists about their funding sources were striking. "The esthetic illusion is that as long as artists don't know where the money is coming from," Burnham said, "many latently guilty consciences are relieved." As a result, he concluded, "the idea of arranging an art exhibition is increasingly untenable."[22]

POLARIZATION

In May 1971, Maurice Tuchman found himself in just such an untenable situation. After five years of planning, Tuchman unveiled his long-heralded "Art and

Technology" exhibition in Los Angeles. Before the show officially opened with extended hours for the public, an international assortment of curators and critics mingled with glittery well-heeled locals ("art mavericks meet mahogany row," according to one observer) at a private party.[23] Outside the museum, performance artist Paul Cotton, dressed in a bunny suit adorned with antennae and carrying a platter of marijuana joints, was arrested. Those who made it past museum security circulated underneath colorful "A" and "T" letters suspended from gallery ceilings while waitstaff kept the VIPs supplied with drinks and hors d'oeuvres.

LACMA's "most innovative and extensive exhibition ever" included nineteen artworks made by sixteen sponsored artists (far less than the seventy-six people listed as "participating artists" in the show's report) and their engineer collaborators.[24] Outside the museum, Claes Oldenburg's *Giant Ice Bag* heaved, twisted, and writhed. Laser beams from Rockne Krebs's *Night Passage* knifed back and forth from a nearby rooftop down to the museum's plaza. Inside, guests walked through a recreation of sculptor Tony Smith's *Bat Cave*, which had shown at Osaka. Visitors also could finally view the new installations not shown in Osaka by artists such as Robert Rauschenberg. His piece, called *Mud-Muse*, was executed in collaboration with engineers from Teledyne, a defense and aerospace contractor in Southern California. The artist meant the piece to mimic the "bubbling activity of the 'paint pots' at Yellowstone National Park." Teledyne's engineers translated Rauschenberg's concept into a large vat filled with a thousand gallons of a thick clay and water mixture. The piece had compressed air inlets along the tank's sides and bottom. Linked to an elaborate electronic system, they responded to ambient gallery sounds to make the thick brown goop erupt into "an ingenious landscape" of gurgling bubbles.[25] Rauschenberg hoped viewers would experience *Mud-Muse* on a "really physical, basic" level.[26] He wasn't disappointed. Artist and critic David Antin observed spectators interacting with *Mud-Muse* so much that they spattered the gallery space "with tangible evidence of their involvement." Posted guards and a "non-interactive" (and presumably less messy) sound track replaced the cybernetic sounds-make-bubbles system.[27]

Perhaps even more striking than the actual art installations was the publication accompanying the show. Antin branded it a "386 page piece of conceptual art," while Jack Burnham likened it to a "shareholder's report."[28] *A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971*—Tuchman's title choice was purposely bureaucratic and banal—presented a detailed chronicle that was blunt and transparent to the point of discomfort for some. Starting with the

Figure 9.2 Poster for LACMA's 1971 "Art and Technology" exhibition by William Richard Crutchfield; Gemini G.E.L., LLC, Art and Technology, 1971, Los Angeles County Museum of Art, Mr. and Mrs. Allan C. Balch Art Research Library. Photo © Museum Associates/LACMA.

Figure 9.3 Artist Claes Oldenburg's *Giant Ice Bag*, which he made in collaboration with engineers and staff from Gemini G.E.L and Krofft Enterprises. Photo © Museum Associates/LACMA and the Oldenburg van Bruggen Studio.

program's origin (including initial opposition from the museum's leaders) and continuing through each artist's interactions with his sponsor, the result was a granular account of the collaborative process (as opposed to a catalog's usual focus on the artworks themselves).

Tuchman's conceptualization was influenced by the publication in 1970 of *The Presidential Report of the Commission on Obscenity and Pornography.* Almost immediately after the official version appeared, an unsanctioned illustrated version emerged that resulted in obscenity charges against its publishers. Tuchman appreciated the level of factual data the Presidential Commission had assembled and wanted to do something similar. "This idea of absolute candor was in my mind from Day One," he said, "I didn't intend it to be subversive. But I wanted it to be an account."[29] A close reading of Tuchman's *Report* also reveals the curator's sly sense of humor at work. Companies that LACMA approached unsuccessfully for sponsorship—including Aerojet, the company Frank Malina helped start two decades earlier—are listed alongside those that proved generous. Likewise, Tuchman's "let it all hang

Figure 9.4 Tony Smith and Cardboard Corporation of America's installment of *Bat Cave* at Expo '70 in Osaka, Japan. Photo © Museum Associates/LACMA, by Ed Cornachio.

Figure 9.5 Robert Rauschenberg (right) working on his installation of *Mud-Muse* at Teledyne Corporation as LACMA curator Maurice Tuchman and an unidentified woman look on. Photo © Malcolm Lubliner.

out" attitude revealed artists' unrealistic demands alongside the intransigence of corporate middle management.

The response from most art critics to the "Art and Technology" exhibition was fairly positive at first. Most major national newspapers featured Tuchman's show and touted the experimental possibilities of future artist-industry collaborations. One writer noted that a few LACMA trustees had called for the curator to be restrained amid some concerns about costs and "wounded feelings" the "controversial" show had provoked. Tuchman—he would not curate another major modern art show for several more years—was quite open himself about the challenges he faced from museum leaders and business executives who displayed "too much hesitancy and fear."[30]

A closer look at the show's participants—this can be seen just from the grid of men's faces on the cover of Tuchman's *Report*—reveals what became the show's main liability for many members of the art world. *All* of the artists included in the exhibition were white men.[31] While this imbalance might have escaped public censure

Figure 9.6 Cover of Tuchman's *Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971*. Photo © Museum Associates/LACMA.

in 1967, when Tuchman was starting the Art and Technology Program, by mid-1971 such an omission seemed a serious lapse in judgment. In June, the Los Angeles Council of Women Artists (or, LACWA, a dig at their county's publicly funded museum) presented its own report to the *Los Angeles Times*. Between 1961 and 1971, it stated, some 713 artists exhibited their work at LACMA. Of these, only twenty-nine were women. And, of the fifty-three solo shows the museum presented, only one was devoted to a woman artist. Finally, an inspection of the museum's permanent galleries showed that only 1 percent of the art displayed was made by women artists and, to add insult to injury, plenty of the artwork featured depictions of nude women as seen through the male gaze.[32]

While decrying broad patterns of underrepresentation, the thrust of the council's condemnation was directed specifically at the Art and Technology Program. Labeling the imbalance of artists as "blatant discrimination," their manifesto noted that "none of the technical advisors" were women either. A lack of representation and diversity appeared as something, unfortunately, that the both art and engineering communities shared. If art-and-technology collaborations were indeed the "wave of the future," they were also part of a movement that excluded women and people of color.[33] Perhaps the best way to remedy this situation, they concluded, was with a civil rights lawsuit. Later, the "Art and Technology" exhibition came to be seen as the primary catalyst for women and underrepresented minorities groups to secure better representation and recognition in the Los Angeles art scene.[34]

For years, art critics who derided the art-and-technology movement labeled it as aesthetically compromised. It wasn't so much that artists and engineers working together was categorically bad (although it clearly discomfited some art writers). Rather, the issue was the quality of the resulting art. Such assessments were not limited to critics. Physicist Richard Feynman damned the LACMA exhibition with faint praise, calling it simply "a good, neat Disneyland job."[35] A. Michael Noll, who had helped pioneer early efforts in computer-generated art at Bell Labs, eventually came to see the whole notion of engineers collaborating with artists "doomed" to be "a mediocre combination of poor art with poor technology."[36] Engineer Gordon D. Friedlander meanwhile criticized not only the supposed novelty of contemporary art and technology efforts but also its practitioners' pretensions. Too often, engineers merely contributed to "the cult of electronic gimmickry," their dabbling producing only an unwanted "avalanche of anarchy and nihilism." Taking a swipe at E.A.T. and other avant-garde efforts, he advised technologists to avoid the "shrapnel bursts" of "spontaneous and unrehearsed happenings," and instead seek shelter in "orderly and planned interdisciplinary ventures."[37]

Tied to these aesthetic appraisals was an ontological issue. *What* exactly was produced when artists and engineers collaborated? These concerns, for example, could be found circling around E.A.T.'s partnership with Pepsi as Billy Klüver made a direct appeal to the company's president to "treat the Pavilion as a work of art."[38] Questions about the status of what was made and exhibited were perhaps most probing when it came to the use of computers to make art and music.[39] Was it really art? Or was it a technologically enabled form of spectacle? Challenging the very nature of what art-and-technology efforts generated was both common among critics and a way of calling the movement's significance into question.

After the LACMA exhibition, however, critics and artists began to attack the art-and-technology movement from a different direction. A new fusillade of critiques regarding ethics spoke less about tastes and styles inside the sheltered sphere of galleries and museums. Instead, they were directed toward the wreckage created when the art world collided with rougher economic, geopolitical, and social realities. One of the more outspoken artists was Gustav Metzger who, working in England in the early 1960s under the rubric of "auto-destructive art," made politically charged pieces that reflected his opposition to the arms race and the commodification of art. Metzger branded technological art as simply "kinetic art plus a lot of money." The result, he said, was a moral crisis as artists were in danger of being "eaten by big business and manipulated by technology." Anticipating scholars' critiques about how the built world reflected political goals, Metzger advised anyone encountering claims that technology was politically neutral to "*reach for your gun!*"[40] Sculptor Richard Serra, a participant in LACMA's Art and Technology Program, was more blunt. Technology was not "power to do something" but "power over someone." Representing a shameful legacy of colonialism, misogyny, and militarism, "technology," he told Tuchman, "is what we do to the Black Panthers and the Vietnamese under the guise of advancement in a materialistic theology."[41]

Such criticisms signaled how much had changed outside the art world since advocates like Klüver and Tuchman had first started their initiatives. Meanwhile, critics' analyses concerning the compromised ethics of art and technology advanced along three broad fronts. The first was the political nature of the art that artist-engineer collaborations produced. For example, Rauschenberg admitted that his *Mud-Muse* displayed little "moral content." Instead, it was about "pure waste, sensualism, utilizing a pretty sophisticated technology."[42] The same might be said about many of the works produced by the art-and-technology movement, either in the United States or overseas. Making overt political statements was typically not its raison d'être. E.A.T. had specifically requested, for instance that the Pepsi Pavilion be free of controversial political messages while Klüver once stated it was "important to keep politics out of art."[43] (However, to be fair, several artists linked at various times to the art-and-technology movement, such as Dan Flavin, Hans Haacke, Yvonne Rainer, and Carolee Schneemann, *did* make art that directly addressed controversial topics, such as the Vietnam War.)[44] While claims of political neutrality might have been tolerated in 1966, they were indefensible five years later.

Artists' acceptance of corporate money (and with it, presumably, corporate values) appeared equally damning. Jack Burnham hoped that the "business moguls" who funded Tuchman's project had picked up on what he believed was the artists' real message. "No one believes that American corporate interests," he wrote, "have any real sense of social responsibility or direction."[45] Criticisms of art and technology mutated into a synecdoche for broader ills plaguing Western society and, in this, participating artists were afforded little sympathy. While one *might* perhaps sympathize with the engineers, who ostensibly were just capitalist lackeys following managers' orders, participating artists had revealed themselves as "collaborators" in the most pejorative sense. As "would-be magi, conmen, fledgling technocrats," artists were "acting out mad science-fiction fantasies." And, instead of reflecting on profound global tragedies, artists had chosen to "freeload at the trough of techno-fascism that had inspired them." Tuchman's *Report* and the Pentagon Papers (first published in June 1971) were, one critic said, similar in how they presented chronicles of "bad faith and mutual deceit." Likewise, both documents revealed the "impulse to expand the market of American technology" regardless of the political or environmental cost. The failure to address the social context in which art and engineering existed would cause both to continue to drift in a "social vacuum," serving as "surrogates for the voice of the social master."[46] By this point, such expansive critiques were obviously no longer about a single art exhibition or even an art movement.

The final prong on which critics skewered the art-and-technology movement was, of course, the ongoing war in Southeast Asia. Besides being complicit in corporatism, art-and-technology participants were likewise pronounced as abettors of American militarism. Surveying the range of companies that contributed to LACMA's program, Max Kozloff judged them a "rogue's gallery of the violence industries" that had "grown to their present bulk through the business of slaying."[47] Even Tuchman acknowledged the caprices of poor timing. "I suspect that if Art and Technology were beginning now instead of in 1967," he wrote in 1971, "many of the same artists would not have participated."[48] Years later, when asked about the criticisms his efforts received, he said simply, "I really lay it all on the Vietnam War."[49]

As vitriolic as some reactions were to art and technology, critics' censure did not produce the movement's decline but rather marked it. In 1972, Jonathan Benthall, a former IBM engineer and correspondent for *Studio International*, noted that many artists had begun to retreat from "the no-man's-land where art overlaps with science and technology."[50] In assessing their withdrawal, critics at the time (and experts since) tended to blame anticorporate attitudes, the mistaken belief in some wholesale rejection of technology, or the corrosive effects of the Vietnam War.[51] While these were proximate causes for the diminished enthusiasm, larger social and economic changes were the prime movers.

Part of this misunderstanding comes from an overemphasis on the artists' world. But in large-scale art-and-technology collaborations, engineers were equal and essential components. Without their participation, there would have been no Pepsi Pavilion or Art and Technology Program. Absent interest and support from engineers and scientists, Kepes's plans for CAVS would have foundered, *Leonardo* would have had fewer article submissions, and shows like "Cybernetic Serendipity" could have not happened. But, in the early 1970s, essential threads that once gave security to the Cold War engineer's professional world were starting to unravel.

Just as the art-and-technology boom was catalyzed by rising corporate profits and the general prosperity of the 1960s, an economic downturn blighted the United States a decade later. In August 1971, the Nixon administration enacted a series of economic reforms designed to stabilize the dollar. At that time, inflation and unemployment were both at about 6 percent. Economists later blamed the so-called Nixon shock as paving the way for subsequent high unemployment and inflation ("stagflation"), conditions further exacerbated by the 1973 oil crisis. When Gerald Ford was sworn in as president in 1974, inflation had risen to 9 percent, unemployment was over 8 percent, and a powerful recessionary wave had hit the United States and rippled outward.[52]

Aerospace companies were particularly affected as a number of high-profile weapons and space programs were either cancelled or concluded. Détente with the Soviet Union and subsequent arms control talks drove companies to make further cuts. To make matters worse, after 1970, federal research funding fell into a steady state, or worse, a declining pattern while the number of advanced degrees awarded in science and engineering declined. When the National Research Council began a study of engineering education in 1980, it did so amid "widespread concerns that the profession was under stress" due, in part, to "adverse student attitudes" toward the profession.[53] Other studies suggested that anywhere between 50,000 and 100,000 engineers were unemployed by the end of 1971.[54] Physicists had similar tales to share with their engineering colleagues as the vicissitudes of the Cold War turned a two-decade-long hiring boom into a bust by 1971.[55]

In Southern California alone, some 160,000 aerospace jobs were lost between 1967 and 1971, as both production workers and highly educated technologists received pink slips. One highly trained aerospace engineer applied for a new job after being fired from McDonnell Douglas Aircraft. His résumé, managers told him, was one of 18,000 they had received.[56] Not captured in these statistics is the surge in divorce rates, mortgage foreclosures, repossessed cars, and other personal hardships and humiliations the recession brought.

One inevitable consequence of this economic turmoil was diminished resources and enthusiasm for artist-engineer collaborations. For several years, scores of companies had contributed money and manpower to artists' projects. Likewise, corporate divisions, like Klüver's former employer, Bell Labs, had tolerated, sometimes even endorsed, employees' extramural activities. In the mid-1960s, when the economy was flush, company managers saw this as a way of keeping engineers happy while helping diversify employees' skills and interests. But, with a recession under way, this now appeared as a luxury few were willing to invest in. As unemployment rates climbed, one can easily imagine the reluctance of a mid-level engineer to ask for time or matériel in order to collaborate with an artist. Engineers, often stereotyped as risk averse and conservative, had increased reasons to keep their heads down and focus on their day jobs. Consequently, the impetus for art-and-technology collaborations was squeezed from two ends—reduced support at the corporate level and diminished motivation and enthusiasm on the part of individual engineers.

REVERBERATIONS

By the mid-1970s, lavishly funded and publicized Big Art efforts appeared as out of fashion as moon landings. Even as the social fabric rent by the turbulent sixties, Watergate, and the end of the Vietnam War was refashioned—this time perhaps as a bright plaid polyester leisure suit—artists' experiments with technology didn't disappear, however. Quite the opposite, in fact. They continued to enthusiastically experiment with technology, albeit on an individual, smaller scale, to the extent that we probably should not think of art-and-technology efforts as having "failed" circa 1972. While there was some decline, relative to the preceding decade's intensity, there was also a redirection of energy. New sensibilities and strategies appeared as art-and-technology advocates and their organizations adapted to changing circumstances.

When he cofounded E.A.T., Billy Klüver predicted that, in time, new institutions would eventually take over the role of brokering creative work at art-and-technology interfaces. By the early 1970s, new university programs were starting to appear that did just that. For example, in 1972, Gerald O'Grady, an English professor influenced by Marshall McLuhan, founded the Center for Media Study at the State University of New York at Buffalo. Over the next two decades, the center's faculty—an eclectic group that included avant-garde filmmakers Steina and Woody Vasulka, multimedia artist Peter Weibel, and video artist Tony Conrad—made (and wrote about) art using an equally diverse assortment of media art.[57] Across the country, the University of California at San Diego started a Center for Music Experiment in 1973, with funding support from the Rockefeller Foundation. Over time, this morphed into the Center for Research in Computing and the Arts with a correspondingly broader focus. These and other university-based programs helped establish a more scholarly approach to both practice and theory around what came to be known as "new media."

A key difference in artists' efforts after 1970 was that many new experiments with technologies didn't require the same degree of collaboration with engineers. For example, Sony's introduction of its Portapak video cameras in 1965 provided artists with a new tool that was relatively affordable and, as the name implied, easy to carry. Video art was quickly accepted by the art world's galleries and museums, in part because of its parallels to the established medium of photography. In 1970, Howard Wise, who had for years exhibited light and movement artists (a diverse cohort that included Frank Malina), announced he was closing his New York gallery with his future efforts directed toward video and television-based art.

Wise made this move partly because the increased scale, complexity, and sophistication of art-and-technology works—think of E.A.T.'s "environments" or Rockne Krebs's monumental laser works—made them increasingly unsuited for galleries.[58] If efforts like LACMA's Art and Technology Program represented the art world's version of Big Science, new mediums like video were analogous to a benchtop lab experiment. At the same time, a new infrastructure of publications and organizations emerged to promote video as a creative tool easily coupled to political and social activism. And while systemic discrimination by museums and galleries didn't vanish, new media forms like video art provided opportunities for women and people of color to experiment with art and technology. Video could, of course, be broadcast via public television, offering artists a new and inexpensive way to show their work and bypass the gallery system. Meanwhile, philanthropic groups like the Rockefeller Foundation and the Ford Foundation generously supported artists who wanted to experiment with new video and television media.[59]

One sign of video art's coming of age was Calvin Tomkins's admiring *New Yorker* profile of Nam June Paik. In 1965, around the time Bell Labs hosted him as an artist-in-residence, Paik had predicted that "artists will work with capacitors, resistors, and semiconductors as they work today with brushes, violins, and junk."[60] A subsequent residency at a Boston public television station allowed Paik to continue his partnership with Shuya Abe, a Japanese television engineer. Together, they made a video synthesizer that could blend, distort, and manipulate images just as musical equivalents did with sound.[61] Like Billy Klüver, whom he knew from the 1960s art scene in New York, Paik believed his artwork would eventually make electronics technologies seem less threatening to the average person.[62]

Although video art received the most attention and legitimacy from the art world, similar stories could be told for other "new" technologies that artists experimented with throughout the 1970s. Computer art (which eventually morphed into commercial and scientific applications like computer graphics and data visualization), holography, and art made using copy machines were similar to video art, if not in prominence, by virtue of their small-scale and relative accessibility. In each of these cases, artists—an increasing number of whom were women—could explore the possibilities of electronic technologies without necessarily requiring a professional engineer's expertise. These new technologies offered women artists a way forward along fresh paths not blocked by men. For example, at the School of the Art Institute of Chicago, artist Sonia Sheridan, with support from the 3M Company, translated several years of experiments with photocopying machines into a new course of study called "generative systems."[63] Meanwhile, *Leonardo* continued to provide a forum where artists—Sheridan was one—as well as technologists could describe such experiments.

On November 9, 1981, Frank Malina died suddenly while working in his Paris studio, putting the journal's future in doubt. (Ironically, Malina was scheduled to travel to Edinburgh that day to attend an international conference on art and science.) Roger, his oldest son, asked Robert Maxwell, whose Pergamon Press published *Leonardo*, for a grace period to see if publication might continue. Trained at MIT and then Berkeley as an astrophysicist, Roger possessed a strong physical resemblance to his father: inquisitive eyes set into gentle, rounded features complemented a patient and deeply curious intellect. Like his father, Roger Malina harbored a strong interest in the arts. Within a year, he took over as *Leonardo*'s executive editor. Under his leadership, *Leonardo* was gradually transformed as both the editorial board and the journal's contents diversified. Special issues devoted to particular topics such as "Art and the New Biology," "Holography as an Art Medium," and "Art and Social Consciousness" appeared. Following Maxwell's death in 1991, the MIT Press took over as *Leonardo*'s publisher. Throughout the 1990s, the journal expanded to become a robust forum for debates about science, art, and technology. Given that more than two decades had passed since the first major art-and-technology wave, *Leonardo*'s authors could also begin to situate their work in a larger critical context provided by historians and new media scholars.[64]

Throughout the 1980s and 1990s, Roger Malina maintained two successful careers. Besides working as an astronomer and lab director at Berkeley and then in France, he became increasingly committed to exploring the interfaces of art, science, and technology both as *Leonardo*'s editor and in his own research. Like his father, Roger Malina became passionate enough about this such that he relinquished his science career and, in 2012, accepted a professorship in art and technology at the University of Texas.

What became of the hundreds of engineers and scientists who, in the 1960s, joined groups like E.A.T.? Did they, like Frank and Roger Malina, see the intersection of art, technology, and science as an opportunity for a new career? Unfortunately, there is no demographic data available to tell us how the art-and-technology wave personally or professionally affected the hundreds of rank-and-file engineers who joined groups like E.A.T. However, personal histories suggest that, for many engineers and scientists, working with artists to "humanize technology" and broaden their own horizons had a lasting impact.

For example, after the LACMA exhibition ended, John Forkner quit Philco-Ford and started working as an independent engineering consultant. While he continued to publish technical papers, Forkner maintained his aesthetic interest in the intersection of light and music.[65] In addition to patenting his Light Display Instrument, Forkner invented a "visual drum," called a *tympanum luminorum*, with which he performed at the Hollywood Bowl.[66] In 1987, a university music department used Forkner's instrument—the *Los Angeles Times* described it as a "handmade art deco gizmo"—to perform Alexander Scriabin's composition *Prometheus: Poem of Fire*. The piece had originally premiered in 1911 as a symphonic work accompanied by a type of “color organ” called a chromola. In the 1987 version, Forkner’s “optical synthesizer” projected colors while laser beams traversed the concert space above the audience.[67] Shortly before he died in 2004, Forkner was working again with Robert Whitman, this time to redesign the artist’s 1967 laser light installation *Solid Red Line*.[68]

Several of Klüver’s engineering colleagues logged similar experiences. Fred Waldhauer eventually left Bell Labs and moved to the Bay Area to design audio technology for hearing aids. Nonetheless, he remained in contact with Klüver and supportive of engineers’ collaborations with artists until his death in 1993. Robert Kieronski, who contributed to *9 Evenings* as a young engineer, moved to the Boston area and worked for ARP Instruments, known for its pioneering electronic synthesizers, and started a group called Art and Technology, Inc. that was modeled on E.A.T. After being laid off in the economic downturn of the early 1970s, he found work again with the US Navy, engineering security systems for nuclear submarines, but continued to make electronic art.[69] Per Biorn, another *9 Evenings* alum, continued working with artists well into the 1990s. For example, Biorn collaborated with Rauschenberg and choreographer Trisha Brown for a 1989 piece called *Astral Convertible*. He and Klüver constructed several freestanding aluminum towers that, besides having the capability to project light and sound, also responded to dancers’ movements. Not surprisingly, dance critics lauded the show’s “chrome-like beauty” but neglected to mention the engineers’ contributions.[70] Even Klüver’s boss, John R. Pierce, who had tacitly encouraged his colleague’s initiatives, worked professionally at the intersection of art and technology. After retiring from Bell Labs in 1971, Pierce eventually took a position at Stanford University as a visiting professor of music. For several years, he and his former Bell Labs colleague (and *9 Evenings* participant) Max Mathews collaborated on electronic and computer compositions.

Having declared that the moment for formal marriages between art and technology was over, Billy Klüver shifted to a diverse array of new projects. Even before Expo ’70 in Osaka had ended, he announced an initiative called Projects Outside Art. For this, E.A.T would solicit proposals from interdisciplinary teams of artists, architects, and engineers who would use “state-of-the-art technology . . . to deal with such subjects as education, health, housing” as well as the environment and transportation.[71] As the name suggests, Projects Outside Art signaled E.A.T.’s continued shift away from art projects. One proposal, for instance, motivated by ecological goals and concerns about feeding a growing population, described a rooftop garden system on top of Automation House as an experiment that might “make it feasible

Figure 9.7 Rehearsal of Trisha Brown's *Astral Convertible*, 1989 (Brown is on the left, in the air), with equipment designed by Billy Klüver and Per Biorn. Image courtesy the photographer, © Mark Hanauer.

to undertake city agriculture on a wide scale."[72] Klüver's desire to unite artists' work with broader issues outside of the art world foreshadowed the emergence of what became known as "social practice" art. Combining activism with aesthetics, social practice was formalized in the early twenty-first century as artists engaged directly with local communities to effect social and political change. As with much of E.A.T.'s earlier endeavors, the focus of artists working in this idiom today is on process and collaboration around issues of social and environmental justice.[73]

Despite its ambitions, only one of the Projects Outside Art saw fruition. Children and Communication was based around two electronic environments, largely designed by Robert Whitman, that were set up in different New York City neighborhoods. Telephone lines, facsimile machines, and telex equipment allowed near-instant communication between them. The core concept was to encourage interaction between children from "different backgrounds and geographic locations," while giving kids the opportunity to use "technology creatively rather than being subjected to it."[74] In the spring of 1971, several hundred children participated in the program, with Klüver and other E.A.T. staff then discussing the outcomes with parents and teachers. Although high-minded in principle, the project also piqued kids' interest in sending not only friendly greetings but profanity ("Josh is a shithead"), threats, and lewd images to one another.[75] *Plus ça change, plus c'est la même chose*.

But, despite the welter of initiatives E.A.T. started in the early 1970s, the organization never regained the prominence it had when Klüver first positioned the organization as a mediator—a "transducer," as he put it—between artists, engineers, and industry. By 1974, Klüver, his attention turning to other topics, told an interviewer that E.A.T. was being "put asleep."[76] Nonetheless, Klüver continued his personal engagement with the art world. In 1973, he and Pontus Hultén collaborated on an exhibition at Stockholm's Moderna Museet that featured works by some two dozen American artists, many of whom had been in E.A.T.'s orbit. Besides continuing to work one-on-one with artists, Klüver also reinvented himself as an art historian. Working with Julie Martin, a former E.A.T. staff associate, out of their Berkeley Heights house near his old office at Bell Labs, they researched the Parisian art scene of the early twentieth century. Their well-reviewed book, *Kiki's Paris*, used the life of Alice Prin, a French model and muse, to explore the community of artists like Picasso, Cocteau, and Man Ray in Montparnasse.[77]

Before his death in January 2004, writers began to solicit Klüver for his recollections, especially as a new wave of art-and-technology activity surged forth in the

Figure 9.8 Interacting with the technology of E.A.T's Children and Communication project. Photo by Shunk-Kender © J. Paul Getty Trust, Getty Research Institute, Los Angeles.

1990s. Klüver's obituary noted that the former engineer's focus on fashioning collaborations had created a "merging of art and technology that has not yet exhausted itself."[78] Likewise, the tribute the *New York Times* published posthumously noted how Klüver and E.A.T. had provided a valuable template for the dozens of new "institutionalized laboratories for art-science interchange" that were popping up.

The art-and-technology movement of the long 1960s reverberated beyond careers and personal lives. Throughout this book, I've described examples of artists and engineers, from Thomas Wilfred and Frank Malina to Rockne Krebs and John Forkner, who patented the ideas and devices that arose from their art-technology experiments. Most of these efforts yielded patents but produced little commercial payoff. However, in a few cases, profitable companies arose out of the art-technology intersection.

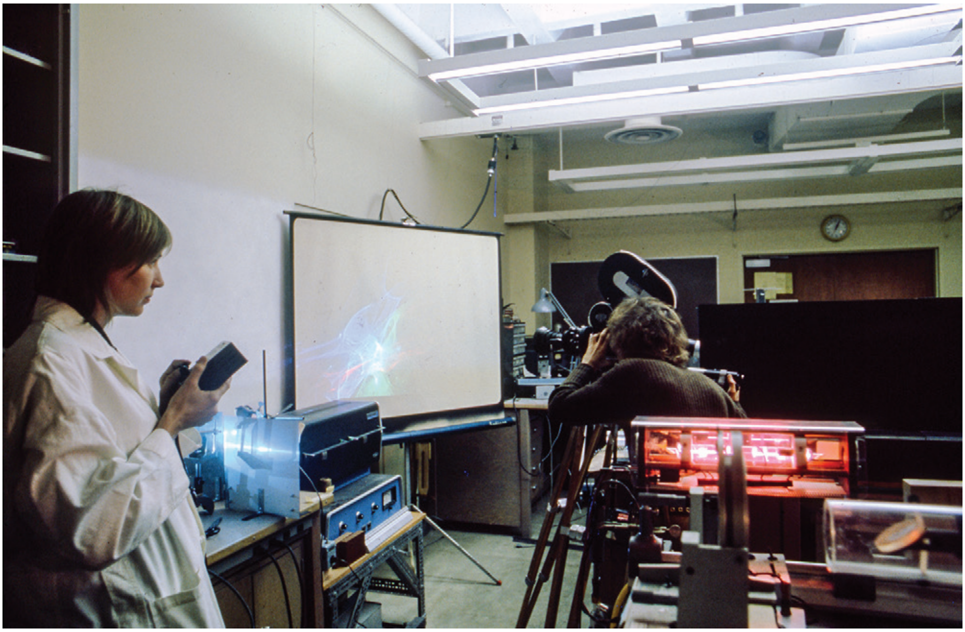

Figure 9.9 Elsa Garmire and Ivan Dryer in her Caltech lab filming laser images, ca. 1971. Image courtesy Elsa Garmire.

For example, after Expo '70 ended, physicist Elsa Garmire continued experimenting with laser light as an artistic medium and as a component for live laser shows. After presenting an example of real-time laser art at a conference on art and technology at the University of Southern California in May 1970, Garmire was contacted by Ivan Dryer. A Los Angeles-based filmmaker, Dryer was also an "astronomy freak" more interested in the "mystiques of space . . . not the mechanics of it."[79] After seeing Garmire's display, Dryer and his colleague, Dale Pelton, visited her Caltech lab and filmed the "marvelous shapes and forms" that Garmire's laser system generated.[80] Dryer soon realized that video footage of Garmire's laser images was aesthetically inferior to seeing the intensity and purity of their colors live and in person.

Before moving into the film industry, Dryer had worked as a guide at the venerable Griffith Observatory—film buffs know it as the location for famous scenes in *Rebel Without a Cause*—in Los Angeles. In the fall of 1970, he arranged for a live demonstration of Garmire's system, accompanied by classical music, in the observatory's planetarium dome. The observatory management, seeing the exhibition as entertainment and not education, was less enchanted. Undaunted, Dryer, Pelton, and Garmire cofounded a company in 1971 called Laser Images. Riffing on the popularity of planetarium shows, they decided to call their product “Laserium.”[81]

Dryer and Garmire worked sporadically to perfect their laser show and attract some commercial interest. Meanwhile, a new director at Griffith Observatory, with a more liberal view of what the public might want to see, agreed to give Dryer and his colleagues access to the planetarium dome. In mid-November 1973, spurred by Dryer’s appearance on a morning television show, some 700 curious people showed up at Griffith. Classical music and art rock provided a lively soundtrack as the spectators watched a panoply of multicolor laser images projected in real time against the planetarium’s starry background. For many visitors, it was likely the first time they had seen a laser’s light effects.

By the time the initial four-week engagement ended, scores of people were being turned away each night for Laserium shows at Griffith. A year after it opened, Los Angeles’ mayor proclaimed “Laserium Month” for the city.[82] Around this time, Garmire began shifting her professional energies back to science and she left Laser Images amicably. Before doing this, however, Garmire contributed technical input and imagery to a short film, filled with “hallucinogenic visuals,” called *Death of the Red Planet*.[83] After leaving Caltech, Garmire went on to have an exceptionally successful career in laser science and physics at the University of Southern California. She eventually became Dartmouth’s engineering dean and president of the Optical Society of America. Years later, Garmire acknowledged that the time she spent with artists influenced her interactions with her students, especially when it came to cultivating a sense of play.[84]

Meanwhile, Dryer’s growing team was soon putting on shows in more than fifteen cities and Laserium became a registered trademark. The popularity of *Star Wars*, released in 1977, with its big-screen spaceship battles and lightsaber duels helped as well. Although they started by using custom-designed equipment, eventually Dryer’s company based its Laserium shows around a standardized system, the details of which are preserved in the patent application he co-filed in July 1975.[85] The system’s heart was a one-watt krypton gas laser and a set of prisms that split the light into four colors. Other optical devices allowed for rapid image movement and the generation of closed linear shapes, Lissajous figures, and so on. An operator (called a “laserist”) seated at a console could play the laser instrument using a variety of switches and joysticks. Meanwhile, a four-track tape deck provided music in stereo and narration for the show that was synched to the visuals. As a live performance, the quality of Laserium shows, as well as the audience's response, depended on the skill and imagination of the system operator.

Laserium's roots stretched back to nineteenth-century displays of electricity and electrical effects for the broader public. And, like conventional planetarium shows that helped popularize astronomy, laser light shows helped make a relatively new technology more familiar.[86] By the 1990s, millions of people worldwide had seen a Laserium show. Dryer remained connected with Laserium and was an enthusiastic promoter of laser light shows until his death in 2017.[87] The idiosyncratic blend of music and spectacle that marked laser light shows made them part of the larger popular culture, with references in comic books, movies, and television shows, such as *The Simpsons*. Meanwhile, the original film, called *Laserimage*, that Dryer prepared with Garmire to first pitch the idea of a laser show to Griffith Observatory's staff was marked for conservation in 2017 by the National Film Preservation Foundation.[88]

Unconventional to be sure, Laserium even had some aesthetic admirers. One art writer, for example, referred to it as the "seeds of what will become the high, universally acclaimed visual art of the future."[89] Given Laserium's penchant for attracting viewers whose appreciation of choreographed laser light was sometimes chemically enhanced, "high" visual art could also assume another meaning. When Billy Klüver had first promoted E.A.T. to engineers and businesspeople, he predicted that artist-engineer collaborations would eventually yield what he called "technical fallout." While maybe not quite the commercial spin-off the former laser physicist had imagined, Laserium persisted long after the initial surge of the 1960s art-and-technology movement faded in intensity.

SIGNAL REACQUIRED

Historians, like engineers, appreciate that correlation is not causation. When a storm is followed by a bridge's collapse, it doesn't mean the former induced the latter. The same holds true for historical events. Throughout this book, I've pointed to events that coincided with the first big wave of art-and-technology activities. The debate that C. P. Snow's "Two Cultures" lecture ignited reflected a desire, perhaps even an imperative, to bring communities of artists, engineers, and scientists together. That corresponded and contributed to a second feature, a continued call for reforming engineers' education and, once they were employed, boosting their outlets for creativity. All of this happened during a period of unparalleled economic growth.

General financial security, even if it didn't cause the wave of art-and-technology initiatives during the long 1960s, enabled and energized them.

By the late 1980s, a new surge of enthusiasm for art-and-technology collaborations was powering up. This time the economic and social contexts were radically different. The Cold War was slowly coming to an end. With its eclipse, a period of uncomfortably dangerous yet stable global order also ended. In the United States and elsewhere, economic policies—whether Reaganomics or Thatcherism—accompanied by deregulation, deficit spending, and a zealous embrace of free markets held the promise of economic prosperity, at least for some people. At the same time, support for the fine arts, once a source of bipartisan agreement among American politicians, waned. Seemingly secure models of "corporate liberalism," in which large and paternalistic hierarchical companies (such as AT&T, which operated Bell Labs) dominated the economic landscape, were upended by macrotrends such as deindustrialization, deregulation, outsourced production, and global trade. Perhaps most importantly, at least in the United States, was the emergence of an anxiety, verging on paranoia, among policy makers and business leaders about being eclipsed by ascending economic rivals like Japan. The end of the Cold War brought both a sense of optimism about free trade and open markets and concerns about how to be economically competitive in a strange new geopolitical environment.

Technological changes accompanied these shifts in corporate thinking. New industries centered around computing, and information processing assumed greater prominence relative to traditional manufacturing. (Artist Nam June Paik, in fact, had coined the phrase "electronic superhighway" in a 1974 report to the Rockefeller Foundation, a phrase he later joked the Clinton administration stole and reworded to "information superhighway.")[90] In 1985, only a small community of mostly academic researchers used the internet, while terms like "cyberspace" were just joining the lexicon. Leap ahead fifteen years and one finds some seventy million Americans accessing the internet annually and a dot-com bubble swelling with irrational exuberance. "High-tech intellectuals" like Nicholas Negroponte—his bestselling book *Being Digital* appeared in 1995—suggested that the immaterial flow of computer bits would soon supplant an older world based on making stuff.

The nature of becoming and being an engineer also transformed. In the long 1960s, at issue was "humanizing" engineering students, cultivating their ingenuity, and diversifying their university coursework. At elite schools like MIT and Caltech, educators often saw the humanities and visual arts as tools to broaden engineering education. Engineers, meanwhile, both as students and as practitioners, attempted to adopt some of the era's environmental and social ideals. However altruistic their attempts might have been, engineering education had little opportunity to fully absorb the radicalism of the 1960s before the next decade's economic shocks reinforced tradition and conservatism.[91]

At the same time, the "social contract" between researchers and the Cold War state—ample funding and relative autonomy in exchange for contributing to national security and prosperity—was eroded by Nixon-era social protests and superpower détente. Although support for basic research remained strong in the United States, an emphasis on practical applications assumed greater importance.[92] During the 1980s, the federal government encouraged tighter coordination between university research and industry needs. One sign of this shift was Ronald Reagan's nomination of Erich Bloch as the new director of the National Science Foundation, an agency ostensibly devoted to "pure research." Lacking a PhD or academic credentials, Bloch—a former IBM engineer and manager—championed the creation of engineering centers on campuses where applied research would further corporate goals.[93]

In the 1980s, a key phrase among engineering educators became "economic competitiveness." The seemingly sudden rise of Japan's high-tech manufacturing sector and the United States' growing trade imbalance, coupled to rhetoric about economic globalization, meant that commercial concerns assumed a new prominence. In terms of job prospects, opportunities for engineers (and their employers) had rebounded after the stagnant seventies, especially in fields like electrical engineering and computer science. As in the 1960s, undergraduate enrollments in engineering programs rose significantly and, once again, national education reports called for "greater exposure to nontechnical subjects."[94] At the same time, newly minted engineers were expected to be flexible, be able to shift between employers and projects with technical dexterity, and have an eye for what was commercially viable.

The new wave of interest in combining technology and art drew on the experiences from the previous surge as well as the infrastructure that pioneers like Malina, Klüver, and Kepes had created. But, as it took form, this wave spread in new directions, exploited different resources, and relied on a new community of sponsors and advocates who had their own rationales for bringing art and technology closer together. This new wave of activity appeared less bound to the traditional sphere of museums and art galleries, and instead unfolded in "studio laboratories" located at universities and corporate research campuses. These enterprises attracted an equally eclectic community of individuals who often saw themselves not strictly as "artists" or "engineers" but as disciplinary hybrids. To secure a sense of the shape this new wave of art and technology took, let's return to the labs and classrooms at MIT.

For decades, MIT's leaders had tried to reconcile the tensions inherent in the school's motto—*Mens et manus* (Mind and hand)—by producing intellectually well-rounded technologists. Gyorgy Kepes's strategy, drawing on the legacy of the Bauhaus, was to create an interdisciplinary community by having artists interact with MIT's engineers and scientists. But Kepes was never able to secure enough institutional support to match his vision. Administratively, the Center for Advanced Visual Studies was originally housed within MIT's School of Architecture, not in the humanities school, which would have made more sense for a visual arts program. It was an uneasy fit as the architecture school itself was in the process of reinvention, seeking to focus less on training new architects—that was something, detractors suggested, trade schools did—and more on research into *au courant* subjects like city planning, computer-aided design, and urban modeling.[95]

Financial strains and an ambiguous fit within MIT's larger research and educational portfolio endured after artist Otto Piene took over as CAVS's director in 1974. Like Kepes, Piene had emigrated to the United States from Europe and, over time, his art making had shifted from painting to technologically informed artworks based on light, kinetics, and interactive environments. A highpoint of Piene's tenure was *Centerbeam*, a complex and technically sophisticated multimedia work assembled by two dozen artists, engineers, and scientists in 1978 on the National Mall in Washington.[96] Featuring laser-projected images, holograms, helium-filled sky sculptures, and a 144-foot-long water prism, the scale of *Centerbeam* was reminiscent of E.A.T.'s pavilion and other large-scale art-and-technology collaborations from a decade earlier.

However, the interfaces between technology, science, and art are expansive, encompassing intellectual as well as practical activities, and CAVS was not the only group at MIT seeking a claim on this territory. Within the School of Architecture, Nicholas Negroponte emerged as Piene's chief rival. The differences between the two men were striking. Born in 1942, Negroponte grew up in Europe and New York in a Greek family made considerably wealthy via the shipping industry. Educated at MIT, he received his SB and MArch degrees in architecture in the 1960s (Kepes was on his thesis committee, as was engineer and computer graphics pioneer Steven Coons), before joining the faculty. No "rumpled, tweedy, musing scholar," the well-tailored Negroponte instead dressed like the corporate executives he networked with.[97] He was also exquisitely well connected to the Cold War establishment. His older brother

John worked as a civil servant and advised Henry Kissinger during talks to end the Vietnam War—his record as ambassador to Honduras in the 1980s was critiqued for his seeming indifference to human rights abuses—and was the Deputy National Security Advisor during the Reagan years. In comparison, Piene often appeared as, well, a rumpled, tweedy, musing scholar, albeit one with an international reputation in the art world.

In 1967, as Kepes was convincing MIT to create the Center for Advanced Visual Studies, Negroponte was starting his own group. In keeping with MIT's desire to create of a "science-based learning environment," his Architecture Machine Group adhered to an ethos of tinkering and bricolage as it experimented with immersive multimedia environments, video displays, and a host of other technologies all centered around the digital computer.[98] Fundamental to all of this was Negroponte's insistence on the importance of learning by doing, building, and, above all, demonstrating. For example, Negroponte's group had built *SEEK* less as a work of art and more as a demonstration that architecture could provide a responsive and interactive environment for its inhabitants (which, in this case, were disruptive gerbils).

At a time when many faculty and students at MIT were discomforted by their school's reliance on military funding, Negroponte's group aggressively pursued it. Money from the Defense Advanced Research Projects Agency (DARPA) supported the Architecture Machine Group's work on computer interfaces, simulations, and immersive environments. In the wake of a successful Israeli commando raid on a hijacked airplane at the Entebbe Airport in 1976, for example, DARPA invested in Negroponte's idea to create a "movie map" of an urban environment using digital images. Foreshadowing Google Maps' Street View, the result was tens of thousands of frames of audiovisual data stored on videodiscs—this was before these devices were commercially available—that provided a virtual tour of Aspen, Colorado. Where CAVS was perennially strapped for cash, Negroponte's group had an inside track to generous federal funding. Many technology managers at government agencies, especially those connected with the Pentagon, had professional ties to MIT, either as alumni or once and future faculty. Marvin Minsky, MIT's artificial intelligence pioneer who helped inspire Negroponte's work, analyzed the school's fortunate situation simply as, "They were us."[99]

Some signs of what a new wave of art and technology would look like emerged when MIT, with encouragement from its former president, Jerome Wiesner, began planning a new building. This "Arts and Media Technology Facility" would host a range of research and teaching done at the generative nexus of art, architecture,

Figure 9.10 MIT's Media Lab director Nicholas Negroponte in 1989, sitting next to computer screen showing "smart yellow pages." Photo by Brian W. Smith/The LIFE Images Collection via Getty Images).

design, science, and engineering. But Piene and Negroponte had radically different ideas for what specific initiatives and programs this new building might house. Seen with the benefit of hindsight, their competing visions indicate how much the enthusiasm for blending art, engineering, and technology had shifted since the late 1960s.

The creation of any new university building is contentious. The details of how Negroponte's idea for the Media Lab first acquired traction and, ultimately, a generous allotment of campus space can be found in piles of reports, memos, and meeting minutes that accumulated over nearly a decade.[100] Taken together, these show how the Media Lab, which became *the* archetype for a new wave of art-technology organizations, swerved from the model CAVS had established earlier. The differences could be boiled down to one comparison: barn versus box.

Advocates for CAVS, not surprisingly, claimed that art making was its central activity. "Technologies are tools," Piene said, that, while important, "do not by themselves constitute artistic expression."[101] Piene, who sometimes quoted Kafka in his reports to MIT's administration, went so far as to suggest that the new building should be designed in the shape of a person, symbolizing the "human concerns" the artists inside were addressing. Their activity would take the form of "happy chaos," unfolding in a "big, undifferentiated, un-designed loft-like building." Piene described it as a "dirty space, barnlike and flexible," which users could configure and reconfigure as they liked.[102]

Negroponte presented a radically different vision. His future facility would combine "film/video, computer graphics, and computer music" in a unified "package," which retained only a "tenuous intersection" with CAVS. Here, the "invention of new media," not making new art, was the goal. And when it came to the building's architecture, he envisioned "neat, clean, acoustically isolated, high-technology, laboratory-like spaces." "We do work in boxes," he explained, "and small boxes at that." Using an analogy that MIT administrators familiar with defense projects could appreciate, Negroponte said, "I see my own office as something closer to the cockpit of an F-14 than a barn." In other words, his merger of technology and art would take place in a carefully controlled, laboratory-like environment ("clean . . . vibration-free . . . dust-free") and not some artist's cluttered atelier. Practitioners' sense of aesthetics would enrich the technology they were experimenting with, not the other way around. Indeed, as Negroponte admitted, "the term 'arts' may lack some propriety in our vision."[103] As one person familiar with MIT's institutional culture later described, what the Media Lab proposed was not making "art" but creating "artful technology."[104]

Piene frequently expressed suspicions that Negroponte's initiative would "subjugate the arts to technology."[105] Nonetheless, CAVS found itself losing the battle on several fronts. First, Negroponte's pitch to anchor the new center around media technologies was both expansive and flexible. In the 1980s, "media" was a rapidly changing area of technology, encompassing video, film, television, computer graphics, and virtual reality. In one proposal, Negroponte presented a Venn diagram, its three partially overlapping circles labeled "Broadcasting (film/video)," "Publishing (graphics)," and "Computers (computer science)." This covered a lot of territory. Designing new media systems, for example, that facilitated human-machine communication—a subject of a long-standing interest for MIT's computer scientists—would "hasten the emergence of a desperately needed new breed of professional," which Negroponte called "the artist-technologist."[106]

For years, CAVS had presented the visual arts as a humanizing influence on students, engineers, and scientists where people might interact on equal footing.

Negroponte presented an alternate vision in which "being digital" would reshape society, economies, and, almost as an afterthought, benefit the fine arts as well. Looking ahead, he imagined a "*Star Wars* generation of much more expressive youngsters" (i.e., future MIT students) who were "prepared to interact with and through machines," especially digital computers. Besides training these future technologists to be "equally at home in the creative and analytical styles of thinking" (again, *Mens et manus*) a broad focus on media technologies would lead to "new modes of education and research, new industries, and new ways of addressing social concerns."[107] Piene countered that Negroponte's "porous" proposals were full of "buzzwords" and "modish applications," promising future payoffs while abandoning the visual arts. "It is verbiage," CAVS supporters fumed, "the only defense for it is that it works to raise money."[108]

In this, Piene was correct. Negroponte had already shown his Architecture Machine Group could capture large government grants and he soon began to secure funding commitments from new patrons. Movie executives in Hollywood were naturally keen to be at the cutting edge of any new media technology. Likewise, profitable computing companies, especially those in Silicon Valley, were more than willing to donate money and hardware in exchange for insiders' perspectives on what MIT's researchers were doing. And, across the Pacific Rim, Negroponte courted executives from now-flush firms like Sony, NEC, and Toshiba. By 1985, Negroponte's brash, sometimes unorthodox approach to fundraising had helped secure $45 million for the Media Lab's new home and initial operating expenses. Meanwhile, Piene's already-modest budget had suffered two successive years of deep cuts.[109] By the time Negroponte's plans had coalesced into concrete and steel, labs and students, MIT's administration described CAVS as something "to be tolerated, rather than supported with any enthusiasm."[110]

Finally, as a model for merging the arts with technology, albeit it obliquely, Negroponte's model for the Media Lab made sense in terms of MIT's own history. The Media Lab fit a pattern of MIT faculty starting interdisciplinary research centers that could bring in lots of outside funding. In time, some of these enterprises evolved to become permanent academic departments in their own right. Perhaps "media arts and sciences," as Negroponte eventually called it, would prove to be like electrical engineering, which had spun off from physics in the early twentieth century and then matured into its own profession.[111] By making these sorts of comparisons, Negroponte presented a convincing model for the future that drew on a familiar sense of the past.

At E.A.T.'s gala events, avant-garde artists and beat poets had mingled with literary intellectuals, art critics, and local politicians. Some of Andy Warhol's silver balloons might be floating about or a new work by Rauschenberg would be on display. In contrast, the Media Lab's outlook from the beginning was resolutely more entrepreneurial than either artistic or academic.[112] When the Media Lab's building was dedicated in October 1985, bestselling author Michael Crichton gave the keynote speech and celebrity businesswoman and lifestyle maven Martha Stewart was hired to cater the event. A special set of dedication booklets praised the organizations whose funding had made the Media Lab possible. Only five of the fifty entries were arts-related. The rest—Eastman-Kodak, ABC, Hitachi, Sanyo, Sony, and so on—were corporations eager to exploit whatever "artful" technologies Negroponte's initiative produced. The lab soon became known for its proof-of-concept technology demonstrations (e.g., a Media Lab motto was "demo or die") for scores of businesspeople visiting MIT each year as part of its Industrial Liaison Program.

Despite its ambiguous status within MIT, CAVS endured. Otto Piene continued to direct it, in fact, until he retired in 1994, at which point Krzysztof Wodiczko took over as director. But the decision to build the Media Laboratory profoundly affected the status of the arts at MIT. Michael Naimark, a CAVS fellow who also worked with Negroponte in planning the Media Lab, recalled how it "fractured the arts community" at the school. On one part of campus, a small and poorly funded group of students and visiting fellows remained committed to making technologically inflected art. Meanwhile, the Media Lab quickly became a hub of technological activity well-funded by corporate sponsors with output largely oriented toward the marketplace. This rupture between two different ways of pursuing art and technology, Naimark wrote in a report assessing opportunities for supporting "tech-based art," was "microcosmic of what was occurring everywhere else in the US."[113] "It's tempting to speculate," said Naimark, "that many people in the creative community may embrace a connection to the marketplace if they knew the motivation was deeper than simply maximizing profit."[114] The question was how to do this while remaining financially sustainable.

Throughout its prime years, Billy Klüver repeatedly stated that E.A.T., if successful, would eventually dissipate, transferring its functions to industry and universities. Seen from this perspective, even as his organization faded in the face of financial difficulty and critics' scorn, Klüver was prescient. But, although many artists still wanted to work with new technologies, the motivations for their experiments changed markedly by the time a new wave of enthusiasm for art and technology was again surging. Starting around 1990, companies and corporate research labs invested significant capital—social as well as financial—into fostering interactions between artists, engineers, and scientists. This time, the rationales were different. It was as if an old signal, sent thirty years earlier, had been reacquired and broadcast again, but at a new frequency, in a new language, and justified by a new logic.

This language and logic was that of *innovation*. Simply put, as phrases like "economic competitiveness" and "creative disruption" saturated management and business literature in the 1990s, the idea took hold that artists' perspectives could help fuel commercial growth.[115] This view wasn't limited to the United States. A special issue of an Australian journal on art and technology from 1987 included a commentary from an official associated with that country's Ministry of Technology. As he saw it, "we need to bring the artists and technology together in order to enable art to better help our drive for innovation."[116] The fact that this message appeared in a relatively obscure art publication might be reason to dismiss it. An opposite reading, however, cuts closer to the bone. Just a few years after the Media Lab debuted, the gospel of "art for innovation" had traveled fast and far from MIT's campus.

This belief appeared especially strong in Silicon Valley, which emerged in the 1990s as a new center of art-and-technology activity. In 1993, for example, Xerox's Palo Alto Research Center (PARC) launched a new artist-in-residence program around the premise that "what artists fundamentally make are . . . new forms and genres of documents." Intended as "an experiment," John Seely Brown, director of the famous lab located adjacent to Stanford's campus, approved the initiative because "what artists pioneer often becomes the norm."[117] While artists at PARC could certainly create "exciting new works of art," the main selling point for company executives was "the creation of new technologies and new uses of old ones."[118] In other words, what this and other similar corporate programs offered most of all was "pathways to innovation" and presumably profit.[119]

At the same time that PARC's collaborative project was taking form, another venture, similar in focus but even more ambitious, was under way less than a quarter-mile away. In 1992, $100 million from Paul G. Allen, a cofounder of Microsoft, fueled the launch of Interval Research, a dot-com era think tank. Allen wanted to explore potentially profitable over-the-horizon technologies—the "interval" between an idea and its integration into everyday life—in areas like broadband communications and digital media. Presented as the dot-com era's follow-up to Bell Labs and other classic industrial research facilities, but without the oversight of the parent company, Interval soon employed some 150 people, including Michael Naimark, as well as clothing designers, musicians, filmmakers and other "new media" artists.[120] Art was valuable at Interval, according to Naimark, for its potential to act as a magnet for "unconventional combinations skills and talents," as a tool to collect information about human behavior, and prompt to send researchers down unforeseen paths, potentially catalyzing new discoveries and intellectual property.[121]

There was historical precedence in the San Francisco Bay area for the conviction that melding art and high technology could yield profits. Years before MIT's Media Lab was launched, John Chowning, an experimental electronic musician at Stanford University, was collaborating with computer scientists at his school. In 1967, they developed a technique called "frequency modulation synthesis" that allowed for the computationally streamlined creation of complex sounds. This discovery was licensed in 1975—the same year Stanford created the Center for Computer Research in Music and Acoustics (the acronym is pronounced "karma")—to the Yamaha Corporation, which, in turn, used it as the basis for a whole series of electronic instruments. If you've ever sung karaoke to music from the 1980s, chances are one of these devices accompanied you. More importantly, for years, Chowning's discovery—made in a music department, and not a biology lab or a computer programmer's garage—proved extremely lucrative for Stanford, bringing in tens of millions of dollars of licensing revenue.[122]

Efforts at the Media Lab, Xerox PARC, Interval, and other newly formed art-and-technology ventures stand as evidence of how the borders between art, engineering, and entrepreneurship continued to be reengineered in the 1990s. A study begun by the National Research Council in 1997 concluded that the computer industry's alliance with the arts had already produced "significant cultural and economic value." Looking ahead, it envisioned "billion-dollar industries, valuable exports . . . and opportunities for global cultural visibility and influence."[123] Meanwhile, C. P. Snow's dualism still proved a powerful and catalytic provocation. Riffing on Snow, Kevin Kelly, then the editor of *Wired*, proclaimed that a new "third culture" was taking shape. Located somewhere at the borderlands of science, art, and technology, this new "pop culture based in technology" offered truth, beauty, and—above all—fresh possibilities, some of which could produce a profit.[124] This is not to say that *all* art associated with the 1990s boom in information technologies tilted toward commercial innovation. But even countercultural events like the Burning Man festival, which started in 1986 in San Francisco before migrating to the northern Nevada desert four years later, gradually acquired a noticeable patina of the marketplace.[125]

Campus administrators, of course, were well aware of the Media Lab's reputation for connecting faculty to rich corporate sponsors. At a pace that only quickened in the feverish hype of the dot-com era, universities began to offer new degrees in hybrid fields such as "media arts and technology" and "digital arts and new media." By the end of the twentieth century, most major universities in Europe and the United States (including several within my own university system) offered some sort of art-based tech or tech-based art program.[126] A new class of practitioners, professionally trained as hybrid engineer-artists, began to graduate, look for jobs, and exhibit their work.

Booms end and bubbles burst, however. In March 2000, the tech-heavy NASDAQ index peaked and then plummeted. Within two years, trillions of dollars in wealth, real or otherwise, had evaporated. As once-flush dot-com companies closed, laid-off technologists shared stories about long waiting lists for U-Hauls out of the Bay Area. Xerox, already sensing the tectonic shifts of economic change, shuttered its artist-in-residence program and, in April 2000, Paul Allen did the same with Interval Research.[127] Artists who might have been positioning themselves to catch a new art-and-technology wave catalyzed by corporate largesse found themselves looking for new opportunities. Meanwhile, engineers, especially those working with information technologies, faced a new wave of layoffs and downsizing.[128]

Around 2000, this second wave of formal art-and-technology activity receded, if only temporarily. Like the first wave, it left behind institutions and infrastructure that could support future endeavors. And, again, professional careers had been rewired along with art itself. Artists and technologists alike sensed more changes forthcoming in their creative practices, especially as personal computing, internet connectivity, and smart phones became seemingly omnipresent. The continued intermingling of technology and art in the pursuit of creative as well as commercial innovation suggested an imminent future in which everyone—engineers, artists, museum patrons, consumers, and citizens—would increasingly be surrounded with artful technology and perhaps technological art.

CONCLUSION: WAVES, LOOPS, AND BUBBLES

> It's in Apple's DNA that technology alone is not enough. It's technology married with liberal arts, married with the humanities, that yields us the results that make our heart sing.[1]
>
> Steve Jobs, 2011

We are in the midst of new surge of advocacy and support for initiatives to further connect the working worlds of engineering, art, and science. All this is still unfolding, so our understanding of recent events and trends is necessarily impressionistic. Like a surfer inside the barrel, we can't really evaluate this current wave's power, profile, and significance until we get more perspective. But it is possible to make some provisional observations while seeing how recent events connect to previous waves of art-and-technology activities.

A gentle caveat lector is in order. I see the current landscape from two angles. On the one hand, I'm a researcher and writer fascinated by the diverse intersections of technology, art, and science as a historical phenomenon. It's something that has held my interest for nearly a decade. But I am also a history professor based at a large public university. I've witnessed some of the events noted here and, like many of my colleagues, I have something at stake in it all.

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Evidence that a new wave of art and technology actually *is* happening is considerable. It appears in the form of gallery shows, new programs launched at laboratories, universities, and museums, heaps of reports, renewed media attention, and a growing number of corporate-sponsored artist-in-residence programs, to name just a few indicators. One could imagine a new bubble of "SciArt"—one term commonly used among some of the actors—inflating even while I was researching and writing this book.[2]

Understanding why waves of interest in art-and-technology surge and then retreat requires us, as I've argued throughout this book, to take into account the larger economic and cultural contexts. The relative wealth and prosperity of the long 1960s catalyzed that era's art-and-technology boom. Likewise, public interest, government support, and corporate investment in information and internet-related technologies in the 1990s gave a powerful boost to another wave of art and technology. The wave of activity today also strongly correlates with broader economic circumstances. This time around, however, the renewed interest in art and technology is happening not only because of expanding financial fortunes but also because of broader economic anxieties.

The Great Recession's warning signs appeared in late 2007 with the crisis in subprime mortgages. Within months, an interlocking ensemble of international economic emergencies reared forth as once-unimaginable bank failures and precipitous stock market declines became the norm.[3] To read journalists' accounts of this period is to see glimpses of a gradual but much greater unraveling. Analysts can seemingly trace almost every contemporary predicament—from the rise of populism and far right movements to increases in economic inequality, a retreat of efforts to address climate change, and the decline of birth rates—back to Great Recession.[4] Few institutions were spared the effects of this turmoil and universities were certainly not among them.

The Great Recession dealt especially punishing blows to the economic underpinnings of public universities as endowments sank and state resources evaporated further. At my own school, departments experienced hiring freezes, the staff was "consolidated," and faculty were given temporary salary cuts (and asked to surrender their office phones, a request with dubious financial impact but good optics). Debate erupted as to whether traditional teaching practices should be creatively disrupted by such innovations as massive, possibly profitable, online courses.[5]

The global economic distress also helped precipitate renewed attention and funding for STEM education (short for Science, Technology, Engineering, and

Mathematics). As economies and communities recovered from the Great Recession, parents and politicians alike encouraged high school students toward *practical* careers in science and technology. As a result, many more incoming college freshmen increasingly opted for STEM disciplines. For example, one set of data suggests that between 2009 and 2016 engineering and science fields saw a 43 percent jump in majors.[6] While humanities professors were concerned about drops in the number of majors in fields like English, theater, and history, science and engineering faculty faced—as they had in the 1960s—the opposite but equally disruptive problem: too many students.

Popular culture and politicians' statements about the relative value of certain fields—computer science versus philosophy, for example—catalyzed this trend further. Wells Fargo, for instance, ran a series of advertisements promoting their "Teen Financial Education Day" with headlines such as "A ballerina yesterday. An engineer today."[7] The company apologized but the message was clear: the arts and humanities were not just in crisis but presented poor choices for aspiring students. (Whether such a crisis actually existed was itself a contentious topic.[8] The propriety of Wells Fargo promoting fiscal responsibility given its role in the Great Recession is another matter entirely.) Meanwhile, state governors derided the arts and humanities as of lesser value for undergraduates.[9] Despite considerable evidence to the contrary, higher education, especially at financially strapped public schools, was misleadingly presented as a zero-sum game in which fields like art history were somehow siphoning support away from STEM fields.[10]

The slow economic recovery that followed was, of course, unevenly distributed. A growing discourse materialized about the "future of work," the rise of the "gig economy," and the "precariat."[11] It's no coincidence that companies like Uber—the gig economy's poster child—started operations in 2009. The belief that people, especially high school and university students, needed to acquire both practical talents *and* a deeper sense of potentially marketable creativity overlapped with the growing popularity of maker spaces and coding camps.[12] *Make* magazine, which promoted entrepreneurship and innovation—traits pitched as essential during the unsteady financial recovery—saw its circulation quadruple in a few short years. Attendance at Maker Faires increased likewise.[13] (A surge of economic growth, at least as measured by stock market indices, that spanned the Obama and Trump years may have also contributed to the reported demise of Maker Media, the movement's most public face, in mid-2019.)[14] Meanwhile, economists and other experts debated whether the relentless pursuit of innovation was itself an unalloyed good.[15]

In the wake of the Great Recession, science and engineering faculty found themselves dealing with the inverse problem their humanities and arts colleagues faced. Enrollments in their fields shot up to often-unsustainable levels as the United States confronted growing economic competition from China. A flurry of new studies about a crisis in STEM education appeared. The National Academy of Sciences alone produced over eighty reports between 2010 and 2018 addressing some aspect of science or engineering education. Of prime concern for educators and policy makers was, as it had been fifty years earlier when the first art-and-technology wave was forming, how and what to teach the next generation of technologists. At the same time, experts believed that incoming college students increasingly wanted their education to have some broader social relevance. So, again, some education professionals saw the integration of the arts into science and engineering curricula as an answer.

If you put "Art" into STEM you, of course, get STEAM. And, starting around 2011, a growing interest in "STEM to STEAM" emerged as a revised approach to education. John Maeda was one of the first prominent proponents of this initiative. Born in 1966 to immigrant parents, he chose to major in Course 6 at MIT (Electrical Engineering and Computer Science) because his father insisted he study something "practical." Maeda got his bachelor's and master's degrees from MIT and then enrolled in the Media Lab's doctoral program. However, he found it to be "more a technology place than an art place . . . so I went away." He eventually earned a doctorate from Tsukuba University's Institute of Art and Design, a program influenced by the Bauhaus. While in Japan, he learned about early computer art made in the 1960s at places like Bell Labs. Maeda returned to the United States in the mid-1990s and rejoined the Media Lab—this time as a faculty member—where he managed a research team called the Aesthetics and Computation Group.[16] Then, in 2008, Maeda accepted an offer from the Rhode Island School of Design (RISD) to become its new president. "STEM to STEAM" became his signature initiative while in that position.

In 2011, the National Science Foundation funded a workshop called "Bridging STEM to STEAM" at RISD. The meeting's participants agreed that a "significant crisis exists in STEM education." However, it was a problem that "visual artists and visual thinkers" could help resolve.[17] After all, Steve Jobs, Apple's CEO and the paradigm of the modern entrepreneur-innovator, had attended Reed College—he took calligraphy courses before dropping out—not MIT. People with skills in the arts, the argument went, could prove valuable to companies and the technologists they employed. Artists, for instance, might help improve communications between technical specialists by helping create "multi-dimensional approaches" to learning.

Although the arts also stood to benefit from such plans, one senses that art primarily existed in such formulations as a resource to improve science and engineering education.[18] It certainly wasn't strictly about helping artists make art. Researchers in the United Kingdom had already highlighted similar concerns. For example, the Wellcome Trust had recently operated a competitive Sciart program. Over the course of a decade, it dispensed some £3 million to scores of visual arts projects that brought artists and scientists together. Wellcome Trust's main goals in supporting these efforts were to increase the public's interest in science (and, presumably, their support), while fostering potentially profitable wellsprings of "innovation and creativity."[19] But the program was also, analysts said, "negatively associated with instrumentalization of the arts."[20]

In a belt-tightening fiscal environment where the arts were increasingly derided as impractical luxuries, STEAM appeared as an opportunity for them to make a contribution to economic growth in ways policy makers and business executives could understand. In 2014, for example, at the Aspen Ideas Festival, a group of high-profile university leaders, including the heads of Berkeley and Harvard, were asked, "What Letter Should We Add to STEM?" Their unanimous answer was "A." Maeda, meanwhile, was invited to present his ideas for education reform at Google's headquarters, TED gatherings, and the World Economic Forum's annual meeting in Davos.[21]

Advocates for STEM to STEAM started building an infrastructure to promote a transformation in education. Program managers at the National Science Foundation, always anxious about their agency's contribution to economic competitiveness, provided grants that supported exploratory STEAM programs. In February 2013, a bipartisan congressional caucus coalesced to endorse STEAM.[22] That same month, James Langevin, a Democratic congressman from Rhode Island, proposed adding art to STEM fields during the reauthorization of the Higher Education Act of 1965. "Art and design," his resolution said, "provide real solutions for our everyday lives, distinguish United States products in a global marketplace, and create opportunity for economic growth."[23]

Evidence, however, suggested the arts and humanities would not be equal partners. In December 2015, I attended a workshop sponsored by the National Academies of Sciences, Engineering, and Medicine. The spirit of C. P. Snow drifted through the room as university leaders and the head of the National Endowment for the Humanities expressed the need for bridging disciplines and avoiding "us versus them" polarities. Despite such good intentions, the meeting began with a quip from one of the academy's representatives: "A scientist, an engineer, an artist, and a humanist are on a sinking lifeboat. There are two life vests. Complete the joke!" While everyone laughed, it was pretty clear who would be feeding the fish.

What emerged out of this meeting was an official study conducted by the National Academies and led by David J. Skorton, then the secretary of the Smithsonian. For more than two years, the committee gathered evidence of best practices when it came to integrating the arts and humanities with STEM fields.[24] A final "consensus report," issued in early 2018, once again repurposed Snow's enduring imagery of the "Two Cultures," now completely unmoored from any historical context of how the idea first arose and drifted to the United States. The report's title came from a statement made by Albert Einstein to the leaders of the YMCA in 1937.[25] The physicist (who was writing about the corruption of knowledge by fascism, not higher education) stated that religion, the arts, and sciences were "all branches from the same tree." Reading the report further, one finds statements stating that prominent scientists (i.e., Nobel prize winners and National Academy members) "were significantly more likely to engage in arts . . . and identify as artists than average scientists and the general public."[26] While this data might be true, one might wonder as to its relevance.

One anecdote, however, suggests the challenges of uncritically integrating the arts and sciences. In 2018, I attended a symposium in Washington held in advance of the report's official release. The event's opening speaker recalled how Abraham Lincoln—the only American president to hold a patent—approved Congress' proposal and signed into being the National Academy of Sciences, whose Act of Incorporation states that the academy will "investigate, examine, experiment, and report upon any subject of science or art" at the behest of the government. This, the speaker (a computer scientist) claimed, was proof that twenty-first-century plans to bring art together with engineering and science sustained an illustrious precedent. What made me squirm was the speaker's unawareness that, in 1863, "art" didn't mean painting, dance, or sculpture.[27] It meant the *mechanical* arts, which is to say it meant technology. Honest Abe was not an early supporter of STEAM or even a joiner of two cultures, but he was being enlisted into the discussion anyway.

The first two major waves of art and technology, in the 1960s and 1990s, were spearheaded by charismatic individuals like Billy Klüver and Nicholas Negroponte. Other than Maeda, who left RISD in 2013 for a position at a Silicon Valley venture capital firm, STEAM has produced few such spokespeople to date. Moreover, compared to E.A.T.'s grassroots efforts to connect artists to engineers, STEAM appears much more as a top-down effort with federal agencies and university administrators leading the way. These actors also appear as the primary audiences for the STEAM message. To date, one doesn't find much discussion of STEAM in the pages of *Artforum* or other contemporary art journals.[28] In the 1990s, excitement about art and technology was firmly linked to anticipation of corporate innovation. Today's STEAM rhetoric takes this a step further. Projected to have an impact beyond company profits, STEAM is steeped in the rhetoric of advancing broader economic goals, including workforce training and regional development.

At the end of the first art-and-technology wave, engineers were typically scorned as lackeys of the capitalist establishment. Leap ahead fifty years and the situation has reversed. Artists and humanists are the ones most often claiming to be marginalized and pressured to succeed in a competitive marketplace. Meanwhile, the "geek-hero" has continued to accrue cultural capital. Engineer-entrepreneurs—whether Elon Musk or the fictional character Tony Stark (a.k.a., Iron Man from the Marvel Comics universe)—now appear as figures worth emulating. CBS built its hit show *The Big Bang Theory* around a story line featuring quirky yet likable men and women who were physicists, engineers, and inventors.[29] (To be fair, fictional technologists possessing rapacious acquisitiveness and questionable ethics still thrived in popular culture circa 2020.) Something similar can be observed with regard to public attitudes about technology. If the late 1960s can be typecast as a time of technophobia, then the decade after the Great Recession was surely one of technophilia, as "Silicon Valley"—the contemporary synecdoche for "technology"—offered profitable privatized remedies for everything from education to public transportation.

This shift in popular perception about technology carried over to the unease many university-based humanists expressed toward STEAM initiatives. As student radicals in the late 1960s had proclaimed, engineers' work often reflected and reproduced existing economic and political power structures. New academic fields evolved in the 1970s to offer critical analyses of science and technology. In the twenty-first century, STEAM appeared to disregard much of this scholarship. Rather than reflecting on the social or economic values that contemporary engineering or science advanced, adding the "Arts" to engineering instruction, for example, often appeared as not much more than a superficial patina. STEAM, critics said, rarely placed the broader, purportedly progressive project of technoscience itself at risk by challenging its core assumptions and built-in biases.[30] Perhaps STEAM is only inflating a bubble of expectations with hot air or maybe it's powering an engine of educational reform. While it's too soon to say what outcomes today's STEAM initiatives might generate (or whether they will evaporate away), as a historian, I understand it first and foremost as another prototype in the cyclic redesign of engineering education that has been happening since the 1950s.

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During the 1960s-era wave of art-and-technology initiatives, advocates like Gyorgy Kepes, Frank Malina, and Billy Klüver promoted the idea that artists could help unveil something about the character of modern technology, perhaps even helping change it. "Technology needs to be revealed," Klüver once said, "and looked at."[31] After all, Klüver had helped Jean Tinguely build *Homage to New York* as a commentary about how people believed technology *should* work. Even if collaborations between engineers and artists often avoided making overt political or social statements, it was thought that they could show aspects of modern technology to their audiences, perhaps just by simply making new tools like lasers or computers appear less threatening and more familiar.

Today, the technologies that induce wonder and dread are very different. Reflecting larger political and social developments, topics such as state surveillance, artificial intelligence, data mining, and online privacy have come to dominate contemporary discourse about technology. Trevor Paglen is one of the most successful artists of the past decade who is working to reveal the power and omnipresence of these technologies. Over the past decade, Paglen's artworks and installations brought him widespread attention, including profiles in the *New Yorker*, a 2017 MacArthur genius grant, and a midcareer survey at the Smithsonian's American Art Museum in 2018.

Born in 1974, at the tail end of the first art-and-technology wave, Paglen grew up on and near military bases in the United States and Germany. After finishing his undergraduate degree, he studied at the Art Institute of Chicago before returning to Berkeley to complete his PhD in geography. While working on his doctorate, Paglen became fascinated by the physical spaces rendered unknowable on contemporary maps, such as those denoting military test sites. For more than a decade, Paglen experimented with a combination of high-power lenses and cameras, some affixed to telescopes, to reveal the secret infrastructure of orbiting reconnaissance satellites and classified military installations. As he put it, this was all about "showing what invisibility looks like."[32] Some of his most uncanny photos, taken legally from a great distance, were blurry and distorted images of defense contractors disembarking from unmarked shuttle planes at a secure Las Vegas airport terminal. Another picture, *Untitled (Reaper Drone)*, was featured on the cover of *Artforum*.[33] It appears at first glance as an impressionistic wash of colors from a desert sunrise. But once the small indistinct black shape—a missile-carrying drone—is seen, the viewer's perspective is altered and it becomes quite difficult *not* to see it.

Paglen gradually shifted his activities to capturing the materiality of the internet. Taking images of underwater fiber-optic cables at banal, right-in-front-of-us locations in Hawaii or Long Island shows how digital infrastructure comes ashore and then disappears.[34] Whereas artists like Jean Tinguely wanted to reveal technology's absurdity, Paglen's work suggested the mundane yet menacingly omnipresent nature of today's communication and surveillance tools. Some of his imagery was featured in the 2014 Oscar-winning documentary *Citizenfour* about Edward Snowden and the National Security Agency's illegal reconnaissance programs.

Although Paglen's work was *about* technology, his early projects did not use technology as an artistic medium in same manner as, say, someone like Rockne Krebs had done with lasers. But gradually a more intense engagement with technology as both subject and material emerged in his work. An example of this is *Autonomy Cube*, a project Paglen unveiled in 2014 in Germany. Its appearance—a cube of thick transparent Plexiglas, about fifteen inches per side, sitting on a white pedestal—referenced Hans Haacke's famous *Condensation Cube*. In his 1963 work, the artist placed a small amount of water inside a cube that responded to feedback from the outside air temperature, condensing on the interior walls to form streaks and patterns.

Paglen designed *Autonomy Cube*, however, to be used as well as seen. Inside its plastic walls are four large circuit boards linked by cables. The cube's electronics create Wi-Fi hotspots that anyone can use to connect to the internet. However, *Autonomy Cube* directs this internet traffic onto the Tor network, a system of volunteer computers that encrypts and anonymizes internet traffic. "What I want art to do," Paglen said in 2012, "is help us see who we are now."[35] By integrating the host institution and those visitors connecting to it into a larger privacy-oriented internet infrastructure, *Autonomy Cube* addresses the pervasive nature of internet surveillance as well as the challenges of privacy.[36]

When I was writing a draft of this chapter, Paglen was preparing to launch—literally—his most ambitious project. Executed in collaboration with the Nevada Museum of Art and Global Western, an aerospace company, *Orbital Reflector* is designed as a nonfunctional satellite. Comparable in some ways to one of the inflatable communications satellites of the 1960s (the type that served as prototypes for the Pepsi Pavilion's mirror dome), engineers built Paglen's satellite as a polyethylene balloon coated with reflective titanium dioxide and packed as the payload of

Figure 10.1 Artist Trevor Paglen, shown with his 2013 *Prototype for a Nonfunctional Satellite*. Image courtesy the artist.

a small CubeSat. Once orbiting some 360 miles above Earth, a carbon dioxide cartridge would inflate the object so that it will be visible to the naked eye as it circles the planet once every ninety minutes or so. After about three months in orbit, the one-hundred-foot-long, diamond-shaped satellite would then fall out of orbit and burn up in the atmosphere.

Paglen envisioned *Orbital Reflector* as a way to draw people's attention upward and consider the almost always unseen web of satellites—some commercial, others classified—whirling overhead us all the time. This would reveal outer space not as a black void but a bustling infrastructure, barely out of our sight and saturated with technology. Like *Autonomy Cube*, *Orbital Reflector* was meant to show an "opposite world" in which technological artifacts are built with different values in mind.[37] Putting a nonfunctional object into space, one critic said, resembled the "simple gesture of a child releasing a balloon into the sky."[38]

In early December 2018, I hiked up to a small mountain peak in the foothills above Santa Barbara. Right on time, the SpaceX rocket carrying Paglen's payload lifted off from Vandenberg Air Force Base, some sixty miles to the northwest. It was a bright, sunny day with crystal-clear visibility so I could track the rocket until it disappeared from sight a few minutes later. By using the whole sky as a canvas, I imagined works like *Orbital Reflector* as a step beyond monumental land art pieces like Robert Smithson's iconic *Spiral Jetty* from 1970, or James Turrell's *Roden Crater*. And, of course, there is considerable irony when seen in the context of Paglen's career trajectory, from photographing satellites to placing his own object into orbit. But, more than anything, I wondered what Frank Malina, whose engineering research had laid the foundation for modern rocketry, would have said about the whole endeavor.

The scale and expense of projects like *Orbital Reflector*—its total price, including launch, approached $1.5 million—loops us back to the ambitions of Big Art projects like E.A.T.'s pavilion. It was art realized with advanced technology, a spectacle which millions of people might be able to briefly ponder. However, the unexpected shutdown of the federal government in late 2018 delayed official permission for the in-orbit inflation of Paglen's sculpture. Ultimately, Paglen's project was doomed to be adrift in space.[39] But, regardless of critics' interpretations or their ultimate fate, projects like *Autonomy Cube* and *Orbital Reflector* would be impossible without assistance from a cohort of programmers and other engineers. Art at this scale and complexity still needs the expertise of technologists.

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More than fifty years have passed since the first major wave of art and technology rose, crested, and subsided. In looking to explain and promote it, advocates often referenced Italian futurism, Russian constructivism, Black Mountain College, or the Bauhaus as exemplars of how artists could work with technology. Likewise, today's artists, engineers, curators, and companies have looked back to the wave of the sixties, deploying the past as a resource to justify and promote new initiatives. The experiences and infrastructures earlier waves left behind provide an antenna of sorts, which contemporary art-and-technology entrepreneurs can use to broadcast new signals about creative collaboration.

In December 2013, for example, the Los Angeles County Museum of Art unveiled its new Art + Technology Lab. Connected to this were sizable grants available to individual artists who would "take purposeful risks in order to explore new boundaries in both art and science."[40] (Technology and science, as in the past, appear as transposable categories.) LACMA's previous experiment in this area provided both lineage and legitimacy for the museum's new effort. "In 1967, LACMA introduced the Art and Technology Program to inspire collaborations with artists and industry," the museum's chief executive explained, "Nearly 50 years later, we've updated the program to encompass the entrepreneurial spirit defining so many industries." In this telling, Maurice Tuchman's original project appeared as both uncontroversial and, if not an outright success, a beta version which had returned useful information.[41]

In its original incarnation, Tuchman's Art and Technology Program provided a high-profile vehicle for the curator, the museum, and sponsoring companies to display themselves on an international scale. When LACMA rebooted the program, new motives appeared. Innovation, and the "maker spaces" where ordinary people could acquire skills to become individual entrepreneurs, were especially valued after the Great Recession. Los Angeles County administrators, perhaps sensing an opportunity to appear responsive to this trend, provided the museum with $300,000 in seed money to jumpstart the Art + Technology Lab. Participating artist John Gerrard—his work uses large-scale, real-time computer simulations to explore energy infrastructures—suggested a similar rationale, intimating that artists were compelled to be more involved with technology or else "they would just continue to make luxury goods." (Recall similar statements Robert Rauschenberg made in 1967 when E.A.T. was formally launched.) Finally, the program's location within an internationally known *art* museum would also self-consciously distinguish it from the growing number of corporate-sponsored artist residencies.[42]

The program's new patrons revealed how much the industrial landscape of Los Angeles had transformed since the late 1960s. Gone were the behemoth defense contractors that made equally outsized products like jet airplanes, missile systems, and nuclear reactors. The new sponsors, firms like Google and Accenture, were primarily content companies that focused on the collection and management of data and information. (SpaceX was one of the few participating companies whose employees still made "things," in the traditional sense.)

Some of the artists LACMA chose from the pool of applicants directly addressed controversies that dogged Tuchman's original program a half century earlier. For instance, Annina Rüst was startled when she first saw the cover of Tuchman's *Art and Technology* report with its array of white, male faces. In LACMA's archives, she also found an image of protestors wearing masks with Tuchman's face and carrying balloons that asked "Where are the women and minorities?" As an exercise in feminist social practice, Rüst's artwork—she titled it *A Piece of the Pie Chart*—addressed the pervasive underrepresentation of women in the workforce. Using a robotic arm and a computer workstation, her assembly line-like installation imprinted pie charts on actual pastries that showed lopsided gender ratios at technology companies and art museums. The installation also produced mailing labels so one could mail a custom-made pie to the organization associated with its data. In *Leonardo*, Rüst described her goal of combining technologies often branded as masculine with activities stereotyped as *feminine*, like baking.[43]

LACMA's rebooted program set out to protect the artist's intellectual property—they would own whatever they produced—and ensure that artists were not providing free labor toward the design and development of corporate products. However, given that artists were again directly collaborating with high-tech companies, issues about the balance of secrecy, openness, and ownership remained. For example, artist John Craig Freeman created an augmented reality piece for Art + Technology. When he described his work in *Leonardo*, Freeman noted that companies' "proprietary, often secret, profit motivation" inevitably resulted in some level of "inherent tension," despite everyone's best intentions.[44]

While the artists were clearly the stars in Tuchman's program, his *Report* gave engineers like John Forkner and Larry Hubby the opportunity to describe their technical contributions as well as record their experiences working alongside artists. In the new version, artists weren't typically paired directly with an engineer or even a single specific company. With the museum playing the role of mediator—shades of E.A.T.—an artist could access expertise from several sponsoring firms (and their engineers) while continuing to work from their own studios. Where Tuchman had based his version on one-to-one relationships between artists and engineers, the twenty-first-century reboot didn't explicitly treat the engineers and the artists as cocreators.[45] Although collaboration and process remained central, the mode and method had changed.

LACMA wasn't the only museum using an example from the past to construct a new art-and-technology initiative. In 2015, the Contemporary Jewish Museum in San Francisco referenced and reimagined E.A.T. with its exhibition "New Experiments in Art and Technology" (NEAT). Proving Nam June Paik's earlier prediction, the artworks for NEAT showed how "computer programming is understood as a new tool or technology that many artists use, not essentially unlike a paintbrush or pencil."[46] The introduction, for instance, of Arduino—small, inexpensive, and easy to program microcontroller boards based on open-source design—gave artists a basic, standardized tool to realize more complex projects. David Mellis, one of the Arduino software developers and a Media Lab alum, noted, "It makes it easier for [artists] to

Figure 10.2 A demonstration of Annina Rüst's *A Piece of the Pie Chart*, April 14, 2015, for LACMA's Art + Technology Lab. Photo © Museum Associates/LACMA.

work with engineers and say ‘This is what I want to do.’ I don’t think it’s replacing the engineer. It’s just facilitating that collaboration.”[47] However, one key difference from other art-and-technology efforts was NEAT’s stated intent to serve as a “celebration of the individual digital artist” as a creator who was “free from direct corporate control . . . and the current climate of Silicon Valley relations with artists.”[48]

This jab was aimed at a dominant trend of the new art-and-technology wave. After 2010, a welter of new artist-in-residence programs emerged, many of them funded by companies based in the Bay Area. Businesses such as Autodesk, Facebook, and Adobe all launched programs to bring artists onto their corporate campuses and, in some cases, interact with their technologists. Facebook, for example, supported artists who would create site-specific pieces for its corporate buildings around the globe that might reflect or even challenge the company’s (sometimes questionable) values.[49] Drew Bennett, an artist Facebook hired in 2012 to run the residency program, made a parallel between the work of visiting artists’ and the company’s coders. “The engineering mindset is one of hacking. The engineer is taking what’s available to them and improving and realizing what you can do with it,” he said, “the artist is doing the same.”[50]

As I’m writing this, scores of art-and-technology programs at companies and universities are supporting some form of creative collaboration.[51] This ensemble included the twenty-first century’s successor to the legendary research facility where Billy Klüver and many of the original E.A.T. engineers worked. In 2016, to coincide with Experiments in Art and Technology’s fiftieth anniversary, Nokia Bell Labs announced a new program, but one with the same name. Like LACMA’s reboot, the telecommunications company contrasted earlier art-and-technology efforts with its contemporary effort. The company’s chief technology officer noted that although E.A.T. had been “a little dormant for the past decades” (something of an understatement), the organization had once been very “avant-garde . . . well ahead of its time.”[52] While blending art and technology might offer Nokia an opportunity to claim a foothold on the “new frontier” of “multimedia sensory art experiences,” it also linked the company back to Bell Labs’ golden years of corporate innovation.[53]

Other even more recent events have looped some of the main actors in art-and-technology’s waves back to the past in outright disturbing ways. In the early 1970s, some artists and art critics attacked the art-and-technology movement for unethical behavior when it came to accepting patronage. Fifty years later, journalists reported extensively on how Joi Ito, as director of MIT’s Media Lab, had, over several years, accepted over $1.5 million from disgraced financier and convicted pedophile Jeffrey

Epstein. At least one professor at the Media Lab—artist Neri Oxman—accepted financial gifts from Epstein, while other lab members resigned in protest.[54] At a rancorous and emotional meeting in September 2019, Ito's attempts at apology were derailed by statements from Nicholas Negroponte. The lab's founder claimed he saw nothing wrong with Ito's actions. "I told Joi to take the money," he reportedly said, "and I would do it again."[55] Supporters of the Media Lab wanly noted that academicians had long accepted money from "dubious characters," while Negroponte himself boasted of having solicited donations from "scoundrels." While hardly a persuasive defense, one could nonetheless draw a thread between critics' claims of amorality or worse when it came to funding art and technology a half century ago and this contemporary controversy.

The landscape of art and technology and that of publishing itself had transformed in the half century since Frank Malina began assembling *Leonardo*'s first issues in his Paris studio. Although the number of individuals and institutions accessing the publication via subscriptions had not changed substantially since the 1970s, its electronic circulation was now much larger. The majority of readers were still from North America and Europe but there was also a growing readership from such places as India, South Korea, and Brazil. Between June 2017 and June 2018, people viewed or downloaded some 500,000 articles and abstracts from *Leonardo*, placing the journal in the top 20 percent of arts publications.[56] In addition to the flagship publication, there was also a supplement devoted to "aesthetic and technical issues in music and the sonic arts," an online-only "electronic almanac," and a book series with more than seventy titles.

By 2018, when *Leonardo* celebrated its fiftieth birthday, the journal had expanded well beyond publications to encompass an international network of people interested in the nexus of art, science, and technology. At sites across North America and Europe, as well as in China, Iran, and Brazil, thousands of people each year attended Leonardo Art Science Evening Rendezvous (LASER) events. These brought artists, engineers, and scientists together for informal lectures and public demonstrations. In a sense, they continued, albeit on a larger scale, the evening salons that Frank Malina had enjoyed hosting in his Paris house.

Leonardo's sprawling set of events and publications—managed from Massachusetts, California, Texas, and two sites in the United Kingdom—signaled a new geographical landscape for art and technology. In the 1960s, the first wave of art and technology had surged in only a few major cities and much of this creative electricity linked back to New York's (relatively small) avant-garde art scene. The hubs of activity shifted over time as Los Angeles and then Silicon Valley became important nodes. Its size has changed as well. In the 1960s, the most active members of the art-and-technology community could have easily fit into a few of the era's jumbo jets. In the still-expanding wave of art and technology, the landscape of activities and actors has become more global, networked, and diverse. Today's art-and-technology community as well as the people and patrons drawn to its work, seem to be both everywhere and in increasing numbers.

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In the 1960s, advocates saw art and technology as an instrument to make new art but also to advance other goals. This alliance would give artists access to new tools and resources while affording engineers access to a new creative partners. Bankrolled by industrial patrons, art and technology could help ordinary citizens better appreciate and adapt to an era of rapid technological change. Creative collaborations might provide a model for improved relations between management and labor. For university administrators, art and technology could help humanize engineers through a more balanced curriculum while still producing highly trained technologists. For business executives, art-and-technology partnerships offered a relatively inexpensive way to burnish corporate images, appease intellectually restless employees, and perhaps profit from future innovation. In all cases, the language of repairing breaches and building bridges between two allegedly estranged cultures provided potent motivation and rhetorical justification for collaboration. Forging this "mutual agreement," as Billy Klüver and Robert Rauschenberg wrote in 1967, between engineers, artists, and industry would ideally "avoid the waste of a cultural revolution," a resonant sentiment when revolutions of all kinds were happening around the planet.

Whether we envision art-and-technology alliances occurring and reoccurring as loops, bubbles, or waves, they were never about just "art" or "technology." Since the 1960s, this Snow-like dichotomy has been gradually replaced with the more accurate "art *is* technology." Indeed, over time, categories like art, technology, engineer, and artist proved anything but static. Historically contingent, their fluidity reflects broader trends and transformations. These included the continued redesign of higher education, the development and availability of new technologies, and the critical role that economic conditions played in catalyzing, amplifying, and attenuating art-and-technology waves.

In the 1960s, the prevailing attitude was that technologists and artists inhabited two disparate and incommensurate cultures. Today, the imagery of gaps and divides still proves a durable presence in academicians' reports and journalists' articles when it comes to writing about science, art, and technology. But the successive art-and-technology movements reveal that engineers and artists can forge communities where they collaborate and create together. Once depicted as worlds apart, these sometimes looked alike not just in their mutual expertise with particular technologies but also in shared values, such as entrepreneurship, adaptability, and a willingness to experiment across disciplinary boundaries.

When we reassess the history of art and technology's practitioners, we're likewise encouraged to think about what they produce. The fusion of art and engineering created objects with a weird ontological status. The products and processes of engineers' and artists' collaborations were, without a doubt, *engineering*. But curators and art critics circa 1970 were often reticent to accept what artists and technologists had made as *art*. Perhaps this hesitancy is changing. In 2017, when the Museum of Modern Art hosted a major retrospective of Robert Rauschenberg's six-decades-long career, its galleries were full of works he made with members of E.A.T. Curators of the show—subtitled "Among Friends"—accurately portrayed the artist's interactions with engineers as a long and productive relationship, not some brief fling. Old prejudices remain, however. A year later, Christie's, the New York auction house, displayed a computer-generated portrait alongside now-conventional pop art works by Andy Warhol and Roy Lichtenstein. Computer scientists and the auction house seemed delighted when it eventually sold for over $430,000, but some artists and art historians cried foul. "It's just so strange," groused one critic, suggesting technological art still retained its shades of liminality.[57]

In the various waves of art and technology that have surged forth since the 1960s, issues as to professional identity persistently lingered. Was someone an engineer, an artist, or a hybrid practitioner? Did such distinctions even matter? But, regardless of one's self-identification, it was a foregone conclusion that whoever made the art was, if nothing else, *a person*. But an even more ontologically precarious question than "is it art?" has arisen. In June 2019, the University of Oxford opened a controversial exhibition titled "Unsecured Futures." The original works displayed were "made" by Ai-Da, the "world's first ultrarealistic humanoid AI robot artist." Ai-Da's art resulted from a collaboration of computer scientists, roboticists, and artists orchestrated by a British gallery director. Ai-Da's paintings, for example, were created using algorithms and artificial neural nets, which plotted image coordinates onto a Cartesian plane.

Human artist Suzie Emery then added oil paint to create the final works, a process that prompted critiques that a robot was getting credit for pieces ultimately made by a woman artist. Ai-Da, its creators say, is an "astute mirror of contemporary currents," supposedly sparking discussions about the nature of technological choices and creative capacity.[58] Hype aside, collectors reportedly paid more than $1 million for Ai-Da's works.

It's now the early spring of 2020 and the current wave of art and technology shows no sign of ebbing. Record gains in the US stock markets suggest yet again how the confluence of art, technology, and science is tied to broader conditions and currents. Last summer, the Getty Foundation announced that the new theme for its formidable Pacific Standard Time initiative would be "Art × Science × LA." Over the next five years, the institution said it would invest $15 million or more to fund exhibitions in the Los Angeles area that explore how "art and science have shared moments of unity, conflict, and mutual insight."[59] The Getty pitched its enterprise as especially well timed given concerns about the pervasive influence and implementation of new technologies (like robots and artificial intelligence). As in previous art-and-technology waves, the best artworks would, ideally, not just exploit technology but reveal something new and surprising about our relations with it.

In 1969, James Seawright, an engineer turned sculptor, told an audience at the Guggenheim Museum that "art is, after all, only a record of people in a time, and this is the time of technology."[60] Today is also a time of technology. Just as art reflects an era's prevailing sensibilities, our technologies reveal our hopes, fears, and ambitions. In their intermingled histories, we see artists acting as inventors, engineers becoming artists, and all of them working toward personal fulfillment, professional success, and sometimes even commercial innovation. Understanding and appreciating these waves of collaboration—how they begin, the art they generate, and how they dissipate—enlightens our understanding of the broader histories of both art and technology. Today, as in the past, new communities of engineers and artists continue to come together and make art work.

NOTES ON SOURCES

During the course of writing this book, I worked with documents and images from a number of archival collections. I also used some collections that are still in private hands, having yet to find to find their way to a permanent institutional home. The sources I consulted are listed below, along with abbreviations used in the endnotes to identify them. Once this project is finished, I'll donate these materials to a scholarly repository.

LOS ANGELES, CA

Art and Technology Program papers, Los Angeles County Museum of Art (AT/LACMA in notes).

Experiments in Art and Technology papers (Accession no. 940003), Getty Research Institute (EAT/GRI).

Experiments in Art and Technology—Los Angeles papers (Accession no. 2003.M.12), Getty Research Institute (EAT-LA/GRI).

Barbara Rose papers (Accession no. 930100), Getty Research Institute (BR/GRI).

PASADENA, CA

John Pierce papers, Huntington Library (JP/HL).

A. Michael Noll papers, Huntington Library (AMN/HL).

BERKELEY, CA

Exploratorium papers (BANC MSS 87/148c), Bancroft Library, University of California, Berkeley (E/UCB).

PALO ALTO, CA

Rich Gold papers (M1510), Special Collections, Stanford University (RG/SU).

NEW YORK, NY

Thomas Wilfred papers (Exhibition Files and the Department of Painting and Sculpture Object Files), Museum of Modern Art Archives (TW/MoMA).

Calvin Tomkins papers, Museum of Modern Art Archives (CT/MoMA).

"Some New Beginnings" exhibition papers, Director's Office Records, Brooklyn Museum (SNB/BM).

"Software" exhibition papers, Jewish Museum (SE/JM).

ITHACA, NY

James J. Gibson Papers, Cornell University (JJG/CU).

Theodore W. Kheel Papers (6021/010), Cornell University (TK/CU).

WASHINGTON, DC

Frank J. Malina papers, Library of Congress (FM/LOC).

Baxter Art Gallery, 1968–1990, Archives of American Art, Smithsonian Institution (BAG/AAA).

Experiments in Art and Technology papers, Archives of American Art, Smithsonian Institution (EAT/AAA). Note that these are filed by year and can be accessed and referred to in this manner.

Howard Wise Gallery records, 1943–1969, Archives of American Art, Smithsonian Institution (HWG/AAA).

Nam June Paik papers, Archives of American Art, Smithsonian Institution (NJP/AAA).

Gyorgy Kepes papers, Archives of American Art, Smithsonian Institution (GK/AAA).

CAMBRIDGE, MA

Center for Advanced Visual Studies Special Collection, Massachusetts Institute of Technology (CAVS/MIT). When I examined these materials at MIT in 2014 and 2015, the materials had yet to be assigned folder or box numbers. Since then, the collection has been organized with some of it placed online at http://act.mit.edu/cavs. Copies of all documents referred to in this book are in my working files. In addition, several collections held in MIT's Institute Archives and Special Collections ("SC/MIT" in notes) were examined for materials related to this book. These included the following:

MIT, Office of the Provost, records of Walter A. Rosenblith (AC 7).

MIT Office of the President and Chancellor, records of Jerome B. Wiesner (AC 8).

MIT, Committee on the Visual Arts records, Center for Advanced Visual Studies Educational Activities (AC 48).

MIT Art Committee, records of 1960–1973 (AC 66).

MIT Office of the President, records of Howard W. Johnson (AC 118).

MIT Office of the President, records of Julius A. Stratton (AC 134).

MIT Office of the President, records of Paul E. Gray (AC 180).

MIT Office of the Arts records (AC 230).

MIT Office of the President and Chancellor, records of Chancellor Paul E. Gray (AC 397).

MIT School of Architecture and Planning, Office of the Dean, records of 1934–1993 (AC 400).

Julius Stratton papers (AC 431).

PRIVATE COLLECTIONS

In the course of researching this book, I also examined numerous collections of documents and ephemera still in private collections. In cases where I've cited these materials, all copies of sources used are in my working files.

Papers related to life of Frank J. Malina; Malina Family Archive; Paris, France.

Papers related to life of Billy Klüver and Experiments in Art and Technology ("BK/JM" in notes) including an unpublished document entitled "Art and Technology: Collected Writings of Billy Klüver" ("BK/CW" in notes); Klüver/Martin archives; Berkeley Township, New Jersey.

Papers related to career of artist Rockne Krebs; collection of Heather Krebs; Washington, DC, ("RK" in notes).

Papers related to career of engineer Fred Waldhauer; collection of Ruth Waldhauer; Palo Alto, California ("FW" in notes).

Papers related to art-and-technology activities; collection of engineer Robert Kieronski, Newport, Rhode Island.

Papers related to computer art and Bell Labs; collection of A. Michael Noll; Summit, New Jersey.

Papers on art and science; collection of John Holloway; Oakham, United Kingdom.

Personal files of Jack Masey related to his work for USIA on Expo '70 in Osaka, Japan ("JM/NYC" in notes).

In addition to documentary evidence, I also was fortunate to be able to take advantage of interviews and oral histories. Some of these were conducted by the author; others were collected by other interviewers. Interviews collected or consulted are listed below.

INTERVIEWS BY THE AUTHOR

Maurice Tuchman (August 19, 2013)

Jack and Beverly Masey (August 26, 2013)

Peter Richards (September 22, 2013)

Jeanne C. Finley (December 10, 2013)

Robert Whitman (December 31, 2014)

Robert Kieronski (June 19, 2015)

Roger Malina (December 1–2, 2015)

A. Michael Noll (April 22–23, 2016)

Laurence Hubby (June 14, 2018)

OTHER INTERVIEWS AND ORAL HISTORIES

Starting in 1969, the Los Angeles public radio station 90.7 KPFK, part of the Pacifica Network, aired a series of interviews and stories, with host Clare Loeb (later Clare Spark) about art and society. Several programs, taped between February and July 1971, featured Loeb's interviews with artists and engineers involved in art and technology, mostly in conjunction with LACMA's Art and Technology Program. The Pacifica Radio Archives has collected many of these (Archive no. BB4458.01-.13). I obtained audio copies of the interviews and had them transcribed. These included on-air interviews with: Robert Whitman and John Forkner; Claes Oldenburg; Jane Livingston; James Lee Byars; Robert Irwin and Ed Wortz; Boyd Mefferd; Billy Klüver; Rockne Krebs; Newton Harrison; and Maurice Tuchman. In addition, a recording was made of an Art and Technology Symposium held in Los Angeles, mid-1971, that coincided with the opening of the *Art and Technology* show at LACMA.

In addition, in 1970 and 1971, as part of E.A.T.'s efforts for the pavilion in Osaka, art critic Barbara Rose and technology writer Nilo Lindgren did several on-site interviews with artists and engineers. Audio tapes of varying quality and, in some cases, transcripts, are preserved in the Experiments in Art and Technology records at the Getty Research Institute. These interviews were consulted and, in some cases, transcribed; where quoted in my book I cite them as part of the Getty collection.

In 2014, art historian Steven Duval conducted a series of videotaped interviews with people from the art-and-technology movement. He kindly shared these interviews with me, which, like the others I consulted, were transcribed. The interviewees include Julie Martin, Maurice Tuchman, John Pearce, Robert Whitman, Jane Livingston, and Elsa Garmire.

Finally, the Archives of American Art in Washington, DC has transcripts of several oral history interviews collected over the years with people associated with the art-and-technology movement or other topics addressed in this book. Interviews consulted include: Jan Wunderman, interviewed September 5, 1965 by Dorothy Seckler; Howard Wise, interviewed February 22, 1971 by Paul Cummings; Rockne Krebs, interviewed January 27 and March 6, 1990 by Benjamin Forgey; and Robert Preusser, in a series of interviews by Robert Brown during 1991.

NOTES

INTRODUCTION

1. Douglas M. Davis, “The New Combine,” *Art in America* 56, no. (1968): 35.

2. Technically, *Live Wire* was an eight-foot piece of plastic string attached to a small electric stepper motor, which was controlled by local area network input. Activity in the network activated the string, its motion a function of digital traffic on the network. The piece is alternatively referred to in some forums as *Dangling String*; I’ve opted to use the artist’s title. Unfortunately, no especially good images of it could be located.

3. Mark Weiser and John Seely Brown, “The Coming Age of Calm Technology,” Xerox PARC (October 5, 1996), http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.129.2275.

4. Biographical information on Jeremijenko comes from several sources, including her current and archived personal web pages which include CVs and press kits as well as Jonah Weiner, “The Artist Who Talks with the Fishes,” *New York Times Magazine*, June 28, 2013, 18–21, 38, https://nyti.ms/10iRiOy.

5. “The Q&A: Natalie Jeremijenko, thingker,” *Economist*, September 20, 2010, https://www.economist.com/prospero/2010/09/20/the-q-and-a-natalie-jeremijenko-thingker.

6. Kevin Berger, “The Artist as Mad Scientist,” *Salon*, June 22, 2006, http://www.salon.com/2006/06/22/natalie/.

7. Mary Lord, “The Scientist as Mad Artist,” *ASEE Prism 20, no. 9* (2011): 24.

8. David Chase, “An Engineer for the Avant-Garde,” *Yale Alumni Magazine*, March/April 2004, http://archive.yalealumnimagazine.com/issues/2004_03/jeremijenko.html.

9. Courtney Eldridge, “Better Art through Circuitry: Questions for Natalie Jeremijenko,” *New York Times Magazine*, June 11, 2000, 25, https://www.nytimes.com/2000/06/11/magazine/the-way-we-live-now-61100-questions-for-natalie-jeremijenko-better.html.

10. C. P. Snow, *The Two Cultures and the Scientific Revolution* (Cambridge: Cambridge University Press, 1959). For the other terms, see Scott Hartley’s *The Fuzzy and the Techie: Why the Liberal Arts Will Rule the Digital World* (Boston: Houghton Mifflin Harcourt, 2017).

11. The term comes from a recent volume, edited by David Cateforis, Steven Duval, and Shepherd Steiner, *Hybrid Practices: Art in Collaboration with Science and Technology in the Long 1960s* (Berkeley: University of California Press, 2018).

12. Stephen Bann, ed., *The Tradition of Constructivism* (New York: Viking Press, 1974), 9.

13. Biographical material on Wilfred as well as technical descriptions of his *clavilux* comes from two catalogs that accompanied shows of his works: Donna M. Stein, *Thomas Wilfred: Lumia—A Retrospective Exhibition* (Washington, DC: Corcoran Gallery of Art, 1971) and Keely Orgeman, *Lumia: Thomas Wilfred and the Art of Light* (New Haven: Yale University Press, 2017), as well as "Biographical Notes" on Wilfred prepared in the curatorial files of the Museum of Modern Art, New York (TW/MoMA).

14. Linda Dalrymple Henderson, *Duchamp in Context: Science and Technology in the* Large Glass *and Related Works* (Princeton: Princeton University Press, 1998).

15. My terminology here was informed by conversations with my much-missed friend and colleague, Ann Johnson, who described "knowledge communities" in her book *Hitting the Brakes: Engineering Design and the Production of Knowledge* (Durham: Duke University Press: 2009). Also, Cyrus C. M. Mody, *Instrumental Community: Probe Microscopy and the Path to Nanotechnology* (Cambridge, MA: MIT Press, 2011).

16. Caroline A. Jones, *The Machine in the Studio: Constructing the Postwar American Artist* (Chicago: University of Chicago Press, 1998), 361.

17. These goals fit into the larger rubric of the 1960s-era "human potential movement," which Maslow contributed to. Sarah Brouilette, "Antisocial Psychology," *Meditations* 26, no. 1–2 (2012–2013): 107–117, https://www.mediationsjournal.org/articles/antisocial-psychology.

18. Collaboration itself has been seen by some art historians as a significant theme in art making after 1950. See, for example, Charles Green, *The Third Hand: Collaboration in Art from Conceptualism to Postmodernism* (Minneapolis: University of Minnesota Press, 2001), as well as the catalog edited by Cynthia Jaffee McCabe, *Artistic Collaboration in the Twentieth Century* (Washington, DC: Smithsonian Institution Press, 1984).

19. Jody Rosen, "Does 'Creative' Work Free You from Drudgery, or Just Security?," *New York Times Magazine*, February 3, 2019, 9–11, https://nyti.ms/2GcWsXR.

20. Matthew Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012).

21. Allan Kaprow, "Should the Artist Become a Man of the World?," *Art News* 63, no. 6 (1964): 34–37, 58–59; Barbara Rose and Irving Sandler, "Sensibility of the Sixties," *Art in America* 55, no. 1 (1967): 44–57; also, Jones, *The Machine in the Studio*.

22. Billy Klüver and Robert Rauschenberg in *E.A.T. News* 1, no. 2 (June 1, 1967): 1.

23. Quote from Simone Whitman, "Theater and Engineering: An Experiment, 1. Notes by a Participant," *Artforum* 5, no. 6 (1967): 28.

24. *E.A.T. News* 2, no. 1 (March 18, 1968): 1.

25. An excellent exploration of Kepes's career and work is John R. Blakinger, *Gyorgy Kepes: Undreaming the Bauhaus* (Cambridge, MA: MIT Press, 2019).

26. Michael Rush, *New Media in Art* (New York: Thames and Hudson, 2005).

27. Barry M. Katz, *Make It New: A History of Silicon Valley Design* (Cambridge, MA: MIT Press, 2015).

28. Jon Agar, "What Happened in the Sixties?," *British Journal for the History of Science* 41, no. 4 (2008): 567–600, doi:10.1017/S0007087408001179.

29. There are many ways one could bookend the long 1960s. While I've chosen one based around technology, a similar one might be based on US politics, starting with Kennedy's assassination in 1963 to the end of the Nixon presidency in 1974.

30. Daniel Bell, *The End of Ideology: On the Exhaustion of Political Ideas in the 1950s* (Cambridge, MA: Harvard University Press, 2000), esp. 313–314.

31. Cateforis, Duval, and Steiner, *Hybrid Practices*, 6.

32. Howard Brick, "Optimism of the Mind: Imagining Postindustrial Society in the 1960s and 1970s," *American Quarterly* 44, no. 3 (1992): 348–380, doi:10.2307/2712981.

33. For example, the index for the post-1945 volume of Hal Foster, Rosalind Krauss, Yve-Alain Bois, Benjamin H. D. Buchloh, and David Joselit, *Art Since 1900: 1945 to the Present* (New York: Thames and Hudson, 2011), doesn't include "technology" or "science," nor is there anything more than an occasional oblique mention throughout its 800-plus pages. Another book, an anthology of essays often used in university courses—Amelia Jones, ed., *A Companion to Contemporary Art since 1945* (Malden, MA: Blackwell, 2006)—includes a section on technology but has notable errors of fact and interpretation. See also, Edward A. Shanken, "Historicizing Art and Technology: Forging a Method and Firing a Canon," in *MediaArtHistories*, ed. Oliver Grau (Cambridge, MA: MIT Press, 2007), 43–70.

34. David Kaiser and W. Patrick McCray, eds., *Groovy Science: Knowledge, Innovation, and American Counterculture* (Chicago: University of Chicago Press, 2016), doi:10.7208/chicago/9780226373072.001.0001.

35. Classic studies include Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940–1960," *Historical Studies in the Physical Sciences* 18, no. 1 (1987): 149–229, doi:10.2307/27757599; Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993); and Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997).

36. Steven Shapin, "The Invisible Technician," *American Scientist* 77, no. 6 (1989): 554–563.

37. Howard S. Becker, *Art Worlds* (Berkeley: University of California Press, 1982).

38. My book expands outward in several directions from scholarship done by my colleague Matthew Wisnioski, whose essay "Why MIT Institutionalized the Avant-Garde: Negotiating Aesthetic Virtue in the Postwar Defense Institute," *Configurations* 21, no. 1 (2013): 85–116, doi:10.1353/con.2013.0006, helped galvanize my thinking at the earliest stages of my research.

39. Derek J. de Solla Price. "Is Technology Historically Independent of Science? A Study in Statistical Historiography," *Technology and Culture* 6, no. 4 (1965): 553–568.

40. Dick Higgins, "Intermedia," *Leonardo* 34, no. 1 (2001): 49–54, https://www.muse.jhu.edu/article/19618, which was originally published in several places, including *Something Else Newsletter* 1, no. 1 (1966). Fluxus cofounder George Maciunas deployed the term "expanded arts" in the winter 1966 issue of *Film Culture*.

41. Elenore Lester, "Intermedia: Tune In, Turn On—And Walk Out?," *New York Times*, May 12, 1968, https://nyti.ms/1LXAv7W. Fred Turner, in his *The Democratic Surround: Multimedia and American Liberalism from World War Two to the Psychedelic Sixties* (Chicago: University of Chicago Press, 2013), proposed the term "surrounds" for these kind of installations, but I find the original term both more explanatory and historically accurate.

42. A distinction further complicated by Steven Shapin in his "Making Art/Discovering Science," *Know* 2, no. 2 (2018): 177–205, doi:10.1086/699899. For a sense of how variable and historically fraught the T-word is, see Eric Schatzberg, *Technology: A Critical History of a Concept* (Chicago: University of Chicago Press, 2018).

43. Arthur I. Miller, *Colliding Worlds: How Cutting-Edge Science Is Redefining Contemporary Art* (New York: Norton, 2014); see also, Leonard Shlain, *Art & Physics: Parallel Visions in Space, Time, and Light* (New York: William Morrow, 1991); Jill Scott, ed., *Artists-in-Labs: Processes of Inquiry* (New York: Springer, 2006); and David Edwards, *Artscience: Creativity in the Post-Google Generation* (Cambridge, MA: Harvard University Press, 2008). In most of the scholarly literature, the

prevailing focus has addressed the art-science nexus. For example, Linda Dalrymple Henderson, *The Fourth Dimension and Non-Euclidean Geometry in Modern Art* (Princeton: Princeton University Press, 1983); and Caroline A. Jones and Peter Galison, eds., *Picturing Science, Producing Art* (New York: Routledge, 1998). A significant exception to this focus on art and science is the topic of computer-generated art, which has received a great deal of attention to the larger exclusion of other art-technology activity. Some recent book-length treatments include: Hannah B. Higgins and Douglas Kahn, eds., *Mainframe Experimentalism: Early Computing and the Foundations of the Digital Arts* (Berkeley: University of California Press, 2012); Carolyn L. Kane, *Chromatic Algorithms: Synthetic Color, Computer Art, and Aesthetics after Code* (Chicago: University of Chicago Press, 2014); Grant D. Taylor, *When the Machine Made Art: The Troubled History of Computer Art* (New York: Bloomsbury, 2014); and Zabet Patterson, *Peripheral Vision: Bell Labs, the S-C 4020, and the Origins of Computer Art* (Cambridge, MA: MIT Press, 2015).

44. A recent and timely look at the landscape of SEAD programs at public universities is Kari Zacharias and Matthew Wisnioski, “Land Grant Hybrids: From Art and Technology to SEAD,” *Leonardo* 52, no. 3 (2019): 261–270, https://www.muse.jhu.edu/article/728399.

CHAPTER 1

1. C. P. Snow, *The Two Cultures and the Scientific Revolution* (Cambridge: Cambridge University Press, 1959), 16.

2. February 15, 1953 letter from Malina to his parents; Folder 10, Box 22, Papers of Frank J. Malina, Library of Congress, Washington, DC (FM/LOC).

3. The most recent and well-researched examination of Malina’s life, especially his rocketry and political activism in the 1930s, is Fraser MacDonald’s *Escape from Earth: A Secret History of the Space Rocket* (New York: PublicAffairs, 2019). Malina wrote about his own activities in rocketry in several essays including “America’s First Long Range Missile Program: The ORDCIT Project of the Jet Propulsion Laboratory, 1943–1946: A Memoir,” in *Essays on the History of Rocketry and Astronautics: Proceedings of the Third Through the Sixth History Symposia of the International Academy of Astronautics*, Vol. II, NASA CP-2014 (1977): 339–383, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19770026104.pdf. In addition, I’ve drawn on several informative oral history interviews including an October 29, 1968 interview with R. Cargill Hall in the NASA Historical Archives and a December 14, 1978 interview with Mary Terrall in the Archives of the California Institute of Technology.

4. A good overview is Hunter Hollins, “Science and Military Influences on the Ascent of Aerospace Development in Southern California,” *Southern California Quarterly* 96, no. 4 (2014): 373–404, doi:10.1525/scq.2014.96.4.373.

5. March 6, 1935 and February 2, 1936 letters from Malina to his parents; Folders 5 and 6, Box 21, FM/LOC.

6. Folder 9, Box 14, FM/LOC.

7. James L. Johnson, “Rockets and the Red Scare: Frank Malina and American Missile Development, 1936–1954,” *Quest* 19 (2012): 30–36; Malina’s involvement with the Communist Party and leftist politics in general while at Caltech is well documented in MacDonald, *Escape from Earth*.

8. My thanks to Fraser MacDonald for sharing the most recent copy of Malina’s file, which he received in mid-2019.

9. “Art,” undated notes (but likely 1937 or 1938), Folder 14, Box 14, FM/LOC.

10. Galerie Henri Tronche, “Frank J. Malina: Extraits de Presse,” 1953; Folder 1, Box 39, FM/LOC.

11. Undated letter, likely late 1944, from Frank Malina to Liljan Malina; Malina Family Archive.

12. October 8, 1944 and October 13, 1944 letters from Frank Malina to Liljan Malina; Malina Family Archive.

13. April 4, 1946 letter from Frank Malina to Liljan Malina; Malina Family Archive.

14. November 28, 1945 letter from Malina to his parents, Folder 5, Box 22, FM/LOC.

15. This episode is detailed in MacDonald's *Escape from Earth*.

16. Malina, "America's First Long Range Missile Program."

17. "The Impact of Science on Society," *Impact of Science on Society*, 1, no. 1 (1950): 1–2; H. H. Krill de Capello, "The Creation of the United Nations Educational, Scientific and Cultural Organization," *International Organization* 24, no. 1 (1970): 1–30.

18. Julian Huxley, *UNESCO: Its Purpose and Philosophy* (Washington, DC: Public Affairs, 1947).

19. Sarton's ideas, presented in his 1931 book *The History of Science and the New Humanism*, are discussed in Roy Porter, "The Two Cultures Revisited," *Boundary* 23, no. 2 (1996): 1–17, doi:10.2307/303805.

20. Huxley, *UNESCO*, 27–28.

21. Frank J. Malina. "Some Reflections on the Differences between Science and Art" in *DATA: Directions in Art, Theory, and Aesthetics*, ed. Anthony Hill (Greenwich, CT: New York Graphic Society, 1969), 134–149.

22. January 1, 1953 report in Malina's FBI file.

23. Correspondence in Folders 6–8, Box 16, FM/LOC.

24. May 31, 1953 letter from Malina to his parents, Folder 10, Box 22, FM/LOC.

25. August 27, 1954 report in Malina's FBI file.

26. Frank. J. Malina, "Electric Light as a Medium in the Visual Fine Arts: A Memoir," *Leonardo* 8, no. 2 (1975): 110, https://muse.jhu.edu/article/599105/summary; see also https://muse.jhu.edu/article/600580/summary.

27. Serge Guilbaut, *How New York Stole the Idea of Modern Art: Abstract Expressionism, Freedom, and the Cold War* (Chicago: University of Chicago Press, 1983).

28. Galerie Henri Tronche, "Frank J. Malina: Extraits de Presse," 1953; Folder 1, Box 39, FM/LOC.

29. May 31, 1953 letter from Malina to his parents; Folder 10, Box 22, FM/LOC.

30. Ibid.

31. Galerie Henri Tronche, "Frank J. Malina: Extraits de Presse," 1953; Folder 1, Box 39, FM/LOC.

32. Gerald Oster and Yasunori Nishijima, "Moiré Patterns," *Scientific American* 208, no. 5 (1963): 54–63. Oster, like Malina, was a scientist who also became a professional artist.

33. On "abstract," see October 25, 1971 letter from Malina to James Gibson; Folder 19, Box 35, FM/LOC. Also, June 11, 1954 letter from Malina to his parents; Folder 11, Box 22, FM/LOC. Malina wasn't alone in his views. In February 1951, Willem de Kooning gave a talk at MoMA in which he also expressed dislike of "abstract," a term that came "from the light-tower of philosophers"; Jed Perl, *New Art City: Manhattan at Mid-Century* (New York City: Vintage, 2005), 121.

34. Frank Popper, "Frank Malina, Artist and Scientist," unpublished 1963 essay; available at https://www.olats.org/pionniers/malina/arts/monographUS.php; also Malina, "Electric Light as a Medium in the Visual Fine Arts."

35. Malina, "Electric Light as a Medium in the Visual Fine Arts."

36. Ralph K. Potter, "New Scientific Tools for the Arts," *Journal of Aesthetics and Art Criticism* 10, no. 2 (1951): 126–134.

37. Jean-Paul Ameline, *Denise René, l'intrepid: Une galerie dans l'aventure de l'art abstrait, 1944–1978* (Paris: Centre Pompidou, 2001), which accompanied an exhibit of the same name.

38. Malina, "Electric Light as a Medium in the Visual Fine Arts," 112.

39. December 17, 1955 letter from Malina to his parents; Folder 11, Box 12, FM/LOC.

40. Malina. "Electric Light as a Medium in the Visual Fine Arts."

41. Frank. J. Malina. “Kinetic Painting: The Lumidyne System.” *Leonardo* 1, no. 1 (1968): 25–33, doi:10.2307/1571902; see also the February 2007 reprint, *Leonardo* 40, no. 1 (2007): 81–90, https://dx.doi.org/10.1162/leon.2007.40.1.81.

42. These are described in John R. Blakinger, *Gyorgy Kepes: Undreaming the Bauhaus* (Cambridge, MA: MIT Press, 2019), 256–264.

43. Frank J. Malina, “Kinetic Painting,” *New Scientist* 25, no. 432 (1965): 512–513.

44. Malina. “Electric Light as a Medium in the Visual Fine Arts.”

45. Frank J. Malina, “Some Reflections on the Differences between Science and Art,” draft essay from late 1964; later published with same name in Anthony Hill, ed., *DATA: Directions in Art, Theory, and Aesthetics* (Greenwich, CT: New York Graphic Society, 1969), 134–149.

46. For example, Thomas Wilfred, “Light and the Artist,” *Journal of Aesthetics and Criticism* 5, no. 4 (1947): 247–255, doi:10.2307/426131.

47. Inferences based on documents in MoMA’s records, 166.1942.

48. Their correspondence, from February and March 1957, is in Folder 5, Box 39, FM/LOC. In May 1962, Malina’s friend, Martin Summerfield, having just seen Wilfred’s *Aspiration* at MoMA, wrote to tell him about the artist. Malina replied that he had first learned of Wilfred in 1957 “from a friend who has one of my kinetic paintings. . . . She sent me no detailed information on it. . . . Until recently, I thought that Wilfred was dead.” May 25, 1962 letter from Malina to Summerfield, Folder 7, Box 39, FM/LOC.

49. February 15, 1957 letter from Malina to his parents; Folder 12, Box 22, FM/LOC.

50. May 25, 1962 letter from Malina to Summerfield, Folder 7, Box 39, FM/LOC. Malina’s US patent, issued in 1964, doesn’t include Wilfred in the “References Cited” section.

51. March 28, 1958 letter from Malina to his parents; Folder 13, Box 22, FM/LOC. The French patent was awarded June 29, 1959. Malina later refiled his application for the US patent; this was awarded as Frank J. Malina, “Lighted, Animated, and Everchanging Picture Arrangement,” US Patent 3,160,975, filed December 11, 1961, issued December 15, 1964, https://patents.google.com/patent/US3160975A/en?oq=US+Patent+3%2c160%2c975; a similar British patent was awarded the same year, titled “Improvements In or Relating to Light-Pattern Generators.”

52. Frank J. Malina, interview by Mary Terrall, December 14, 1978, transcript, Oral History Project, California Institute of Technology Archives, Pasadena, http://oralhistories.library.caltech.edu/149/.

53. Correspondence between Haley and Malina, the key pieces of which date from June–July 1958, are in Folder 7, Box 2, FM/LOC.

54. November 17, 1960 letter from Malina to his parents; Folder 14, Box 22, FM/LOC.

55. Malina, “Electric Light as a Medium in the Visual Fine Arts.”

56. A detailed (undated but likely 1965 or 1966) description of a “kusic” system, written by Dominique Bouffier, an engineer who worked with Malina, appears in Folder 2, Box 41, FM/LOC.

57. In 1964, for instance, he corresponded with a British psychologist about a French-made device called a “Somnidor,” which used lighted forms on a screen to cure insomniacs; June 8, 1964 letter from J. H. Peel to Malina; Folder 7, Box 41, FM/LOC.

58. Frank J. Malina, “Comments on the Kinetic Mural ‘The Cosmos’ at the Pergamon Press, Oxford,” December 25, 1966, Malina Family Archive.

59. Untitled and undated—likely September 1965—film clip; Malina Family Archive, copy in the author’s files.

60. Malina, “Some Reflections on the Differences between Science and Art”; similar sentiments appear in Malina’s 1964 draft of this essay; Folder 3, Box 42, FM/LOC.

61. Malina, “Some Reflections on the Differences between Science and Art.”

62. Bruce V. Lewenstein, "The Meaning of 'Public Understanding of Science' in the United States after World War II," *Public Understanding of Science* 1, no. 1 (1992): 45–68, doi:10.1088/0963-6625/1/1/009.

63. "Techniques: Luminal Music," *Time,* April 28, 1967, 36, 40–41.

64. Roger F. Malina, in discussion with the author, December 7, 2015; copy in the author's files.

65. Based on my survey of the Malina family guest books shared by Roger F. Malina.

66. This phrasing, from a self-description by the "defense intellectual" Albert Wohlstetter, applies equally to Malina; see Pamela M. Lee, "Aesthetic Strategist: Albert Wohlstetter, the Cold War, and a Theory of Mid-Century Modernism," *October* 138 (Fall 2011): 18n7; see also Pamela M. Lee, *Think Tank Aesthetics: Midcentury Modernism, the Cold War, and the Neoliberal Present* (Cambridge, MA: MIT Press, 2020).

67. Popper's recollections come from an interview between him and Véronique Wiesinger, which is included in Jean-Paul Ameline, *Denise René, l'intrepid: Une galerie dans l'aventure de l'art abstrait, 1944–1978* (Paris: Centre Pompidou, 2001).

68. Joseph Nechvatal, "Origins of Virtualism: An Interview with Frank Popper," *Art Journal* 63, no. 1 (2004): 62–77, doi:10.1080/00043249.2004.10791116, http://www.eyewithwings.net/nechvatal/popper/intervewww1.html; see also Reg Gadney, "Kinetic Art," *Interdisciplinary Science Reviews* 42, no. 1–2 (2017): 180–192, doi:10.1080/03080188.2017.1297169.

69. Frank Popper, "Kinetic Art and Our Environment," *Granta,* April 1964, 12–13.

70. William Moritz, *Optical Poetry: The Life and Work of Oskar Fischinger* (Bloomington: Indiana University Press, 2004).

71. An early example of this juxtaposition is an essay by Jean Cassou, the director of the *Musée d'Art Moderne de la Ville* in Paris, "Vers un art cinétique," *Prévues*, no. 113 (July 1960): 67–71.

72. Hilton Kramer, "One Inventor, One Pasticheur," *New York Times*, November 28, 1965, https://nyti.ms/1iIdX2A.

73. Nicolas Schöffer, *Le Spatiodynamisme* (Paris: Société Française d'Esthétique, 1955).

74. Carlotta Darò, "Nicolas Schöffer and the Cybernetic City," *AA Files,* no. 69 (2014): 3–11.

75. Jean Cassou, "Nicolas Schöffer," in *2 Kinetic Sculptors: Nicolas Schöffer and Jean Tinguely, Jean Cassou, K. G. Hultèn, and Sam Hunter* (New York: Jewish Museum, 1966), 17.

76. Contemporary views on Schöffer and his works come from Frank Popper, "Movement & Light in Today's Art," *UNESCO Courier*, September 1963, 13–23; Frank Popper, *Origins and Development of Kinetic Art* (Greenwich, CT: New York Graphic Society, 1968), 134–137; and Jack Burnham, *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of this Century* (New York: George Braziller, 1968); see also, Stephen Bann, et al., *Kinetic Art: Four Essays* (St. Albans, England: Motion Books, 1966). A recent perspective is Arnauld Pierre, ed., *Nicolas Schöffer: Space, Light, Time* (New Haven: Yale University Press, 2018).

77. Frank Popper, "Light and Movement," *Art and Artists* 1, no. 1 (1966): 8–11; October 3, 1966 letter from Malina to Popper; Folder 8, Box 41, FM/LOC.

78. George W. Rickey, "The Morphology of Movement: A Study of Kinetic Art," *Art Journal* 22, no. 4 (1963): 220–231, doi:10.1080/00043249.1963.10794433.

79. From manifesto and statements included in GRAV and Denise René, eds., *Groupe de Recherche d'Art Visuel: Paris 1962* (Paris: Galerie Denise René, 1962); also quoted in Burnham, *Beyond Modern Sculpture*, 282–283.

80. Umberto Eco, "Arte programmata: Arte cinetica, opere moltiplicate, opera aperta," in *Arte programmata: Arte cinetica, opere moltiplicate, opera aperta* (Milan: Officina Arte Grafica Lucini, 1962); see also Lindsay Caplan, "From Collective Creation to Creating Collectives: *Arte programmata* and the Open Work, 1962," *Grey Room* 73 (Fall 2018): 55–81.

81. Malina, "Some Reflections on the Differences between Science and Art."

82. Gadney, "Kinetic Art."

83. John Canaday, "The Whitney Annual, or 'How About Next Year?,'" *New York Times*, December 12, 1965, https://nyti.ms/1Pt6jWQ.

84. "The Movement Movement," *Time*, January 28, 1966, 64–69.

CHAPTER 2

1. J. H. McPherson, "How to Manage Creative Engineers," *Mechanical Engineering* 87, no. 2 (1965): 33.

2. American Society for Engineering Education, *General Education in Engineering: A Report of the Humanistic-Social Research Project* (Urbana, IL: American Society for Engineering Education, 1956), 2–3, https://catalog.hathitrust.org/Record/001959328.

3. Gary Lee Downey, "Low Cost, Mass Use: American Engineers and the Metrics of Progress," *History and Technology* 23, no. 3 (2007): 289–308, doi:10.1080/07341510701300387; Atsushi Akera and Bruce Seely, "A Historical Survey of the Structural Changes in the American System of Engineering Education," in *International Perspectives on Engineering Education: Engineering Education and Practice in Context*, ed. Steen Hyldgaard Christensen et al. (New York: Springer, 2015), 1:7–32, doi:10.1007/978-3-319-16169-3_1.

4. Terry S. Reynolds, "The Engineer in 20th-Century America," in *The Engineer in America: A Historical Anthology from Technology and Culture*, ed. Terry S. Reynolds (Chicago: University of Chicago Press, 1991), 169–190.

5. American Society for Engineering Education, *General Education in Engineering*, 5.

6. Readers familiar with the history of technology will see my indebtedness in this chapter to Matthew Wisnioski's work on the intellectual culture of American engineers in the 1960s, especially his book *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012) which, in turn, was based on his dissertation "Engineers and the Intellectual Crisis of Technology, 1957–1973" (PhD diss., Princeton University, 2005), ProQuest (305420048).

7. C. P. Snow, "The Two Cultures," *New Statesman and Nation* 52, no. 1334 (October 6, 1956): 413–414.

8. The original book was C. P. Snow, *The Two Cultures and the Scientific Revolution* (Cambridge: Cambridge University Press, 1959). I've drawn on the 1993 edition, which includes an excellent commentary by Stefan Collini as well as Snow's 1963 reevaluation of his argument. Also, valuable for situating the Two Cultures debate in a larger context is Guy Ortolano, *The Two Cultures Controversy: Science, Literature and Cultural Politics in Postwar Britain* (New York: Cambridge University Press, 2011).

9. Stefan Collini, introduction to *The Two Cultures and the Scientific Revolution*, by C. P. Snow (New York: Cambridge University Press, 1993), xv.

10. Snow, *The Two Cultures and the Scientific Revolution,* 30–32.

11. F. R. Leavis, "The Two Cultures? The Significance of C. P. Snow," *Spectator,* March 9, 1962, 297–303.

12. David Edgerton, "C. P. Snow as Anti-Historian of British Science: Revisiting the Technocratic Moment" *History of Science* 43, no. 2 (2005): 187–208, doi:10.1177/007327530504300205.

13. William H. Davenport, *The One Culture* (New York: Pergamon Press, 1970), 1.

14. J. Tuzo Wilson, "Two Worlds of the Modern Mind that Seldom Meet," *New York Times*, January 3, 1960, https://nyti.ms/1kPcp8O.

15. Reactions to Snow's book in the United States is discussed in Ortolano, *The Two Cultures Controversy*, 59–60.

16. John L. Rudolph, *Scientists in the Classroom: The Cold War Reconstruction of American Science Education* (New York: Palgrave, 2002); David Kaiser, "Cold War Requisitions, Scientific Manpower, and the Production of American Physicists after World War II," *Historical Studies in the Physical and Biological Sciences* 33, no. 1 (2002): 131–159, doi:10.1525/hsps.2002.33.1.131.

17. "The Discipline of the Scientific Method," *Nature* 184, no. 4683 (1959): 295–296; "The Two Cultures and the Scientific Revolution," *Physics Today* 14, no. 9 (1961): 62–63, doi:10.1063/1.3057748; Lloyd Fallers, "C. P. Snow and the Third Culture," *Bulletin of the Atomic Scientists* 17, no. 8 (1961): 306–310, doi:10.1080/00963402.1961.11454255.

18. C. P. Snow, *The New Men* (New York: Scribner, 1954), 176.

19. National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–1966* (Washington, DC: US Government and Printing Office, 1968). Also, Ronald Kline, "An Overview of Twenty-Five Years of Electrical and Electronics Engineering in the Proceedings of the IEEE, 1963–1987," *Proceedings of the IEEE* 78, no. 3 (1990): 469–485, doi:10.1109/5.52226.

20. T. F. Jones, "Poles and Zeros," *Proceedings of the Institute of Radio Engineers* 50, no. 2 (1962): 129, doi:10.1109/JRPROC.1962.287971.

21. Responses published in *Proceedings of the Institute of Radio Engineers* 50, no. 6 (1962): 1547–1551, doi:10.1109/JRPROC.1962.288198).

22. James M. Lufkin, "The Implications for Engineers of C. P. Snow's 'Two Cultures,'" *IEEE Transactions on Engineering Writing and Speech* 7 no. 3 (1964): 8–15, doi:10.1109/TEWS.1964.4322575.

23. Jamie Cohen-Cole, *The Open Mind: Cold War Politics and the Sciences of Human Nature* (Chicago: University of Chicago Press, 2014), esp. chapter 1.

24. James R. Killian, "The Obligations and Ideals of an Institute of Technology," April 2, 1949 inaugural address, Massachusetts Institute of Technology, Mid-Century Convocation on the Social Implications of Scientific Progress records, 1, Massachusetts Institute of Technology, Libraries, Department of Distinctive Collections, https://archivesspace.mit.edu/repositories/2/archival_objects/55250; see also, Christophe Lécuyer, "The Making of a Science Based Technological University: Karl Compton, James Killian, and the Reform of MIT, 1930–1957," *Historical Studies in the Physical Sciences* 23, no. 1 (1992): 153–180.

25. Frederick E. Terman, "Electrical Engineers Are Going Back to Science!" *Proceedings of the Institute of Radio Engineers* 44, no. 6 (1956): 738–740, doi:10.1109/JRPROC.1956.274963.

26. American Society for Engineering Education, *General Education in Engineering*, 6.

27. Atsushi Akera, "The MIT Lewis Survey: Creating a Cold War Blueprint for a Technological University" (paper presented at the 119th ASEE Annual Conference and Exposition, San Antonio, TX, June 12, 2012), https://www.asee.org/public/conferences/8/papers/3854/view. See also, pages 94–96 in Matthew Wisnioski, "Why MIT Institutionalized the Avant-Garde: Negotiating Aesthetic Virtue in the Postwar Defense Institute," *Configurations* 21, no. 1 (2013): 85–116, doi:10.1353/con.2013.0006.

28. The idea of fostering "visual literacy" also figured large in the rational for Harvard's new Center for Visual Studies, which opened in 1963. Kepes declined an initial offer to direct it. See chapter 5 of Anna Vallye, "Design and Politics of Knowledge in America, 1937–1967: Walter Gropius, Gyorgy Kepes" (PhD diss., Columbia University, New York, 2011), ProQuest (868518343).

29. Gyorgy Kepes, *Language of Vision* (Chicago: Paul Theobald, 1944) and *The New Landscape in Art and Science* (Chicago: Paul Theobald, 1956); also, Anna Vallye, "The Middleman: Kepes's Instruments," in *A Second Modernism: MIT, Architecture, and the 'Techno-Social' Moment*, ed. Arindam Dutta (Cambridge, MA: MIT Press, 2013), 144–185.

30. "The Report of the Committee for the Study of the Visual Arts at the Massachusetts Institute of Technology, 1952–54," copy in Folder 11, Box 1, AC 66, MIT/SC.

31. Robert Preusser, “Relating Art to Science and Technology: An Educational Experience at the Massachusetts Institute of Technology,” *Leonardo* 6, no. 3 (1973): 199–206, https://www.muse.jhu.edu/article/597214; also, Robert Preusser, interview by Robert Brown, 1991, transcript, Archives of American Art, Smithsonian Institution, Washington, DC.

32. David Kaiser, “Elephant on the Charles: Postwar Growing Pains,” in *Becoming MIT: Moments of Decision, ed.* David Kaiser (Cambridge, MA: MIT Press, 2010), 103–122.

33. Preusser, “Relating Art to Science and Technology,” 202.

34. Julius A. Stratton, *Science and the Educated Man: Selected Speeches of Julius A. Stratton* (Cambridge, MA: MIT Press, 1966).

35. William H. Whyte, *The Organization Man* (Philadelphia: University of Pennsylvania Press, 2002), 81.

36. The article Whyte cited was “Interrupting the Great Conversation” by labor journalist George H. Tichenor in the March 1955 issue of *Technology Review*.

37. Samuel C. Florman, “Engineers and the End of Innocence,” *Technology and Culture* 10, no. 1 (1969): 14–16.

38. Descriptions from C. C. Furnas and Joe McCarthy, *The Engineer* (New York: Time, 1966).

39. This idea of sensibility is adapted from several sources, including Susan Sontag’s essay “Notes on Camp,” which appears in *Against Interpretation and Other Essays* (New York: Picador, 1966); Daniel Wickenberg, “What is the History of Sensibilities: On Cultural Histories, Old and New,” *American Historical Review* 112, no. 3 (2007): 661–684, doi:10.1086/ahr.112.3.661; and George Cotkin, *A Feast of Excess: A Cultural History of the New Sensibility* (New York: Oxford University Press, 2016).

40. Robert Perrucci and Joel E. Gerstl, *Profession Without Community: Engineers in American Society* (New York: Random House, 1969).

41. National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–1966* (Washington, DC: US Government and Printing Office, 1968); Engineers Joint Council, *A Profile of the Engineering Profession* (New York: Engineers Join Council, 1971).

42. A. Michael McMahon, *The Making of a Profession: A Century of Electrical Engineering in America* (New York: Institute of Electrical and Electronics Engineers, 1984), 257; Furnas and McCarthy, *The Engineer*, 98.

43. Frederick E. Terman, “Education in 2012 for Communication and Electronics,” *Proceedings of the IRE* 50, no. 5 (1962): 570–571, doi:10.1109/JRPROC.1962.288363.

44. J. D. Ryder, “Spectral Lines,” *IEEE Spectrum* 2, no. 1 (1965): 49, doi:10.1109/MSPEC.1965.5531876. Numbers based on IEEE annual reports.

45. This claim, from electrical engineer Ernst Weber, appeared in an advertisement titled “Technical Obsolescence” from Airborne Instrument Laboratory in *IEEE Spectrum* 3, no. 2 (1966): 5. Similar claims came from leaders in other fields.

46. “Publications: Where They’re Going,” *Chemical Engineering Progress* 63, no. 3 (1967): 29–34.

47. Published in *IEEE Spectrum* 4, no. 4 (1967): 133.

48. Advertisement for Sylvania Electronic Systems, *IEEE Spectrum* 2, no. 9 (1965): 129.

49. Data is from Stanley S. Robin, “The Female in Engineering,” in *The Engineers and the Social System*, ed. Robert Perrucci and Joel E. Gerstl (New York: Wiley, 1969), as well as Amy Sue Bix’s excellent study of women in engineering *Girls Coming to Tech! A History of American Engineering Education for Women* (Cambridge, MA: MIT Press, 2014). On the masculine character of technology and engineering, see Ruth Oldenziel, *Making Technology Masculine: Men, Women, and Modern Machines in America, 1870–1945* (Amsterdam: Amsterdam University Press, 1999).

50. Joseph Whitehill, *The Way Up* (New York: Dell, 1959); the original title was *The Angers of Spring*. My thanks to Megan Prelinger for background information on this book.

51. According to Google's Ngram viewer, sometime between 1968 and 1969, "technology" surpassed both "engineer" and "engineering" in terms of frequency of appearances in books. This impression is confirmed by citation frequencies in the *New York Times* presented by Wisnioski in *Engineers for Change*, page 13, a phenomenon he refers to as a "semantic reversal."

52. "Poles and Zeros," *Proceedings of the IEEE* 51, no. 4 (1963): 551, doi:10.1109/PROC.1963.2198.

53. Recounted in "Letters and Comments," *Mechanical Engineering* 89, no. 2 (1967): 84.

54. For example, Arnold J. Gully, "The Engineer and the Technician: Their Similarities and Differences," *Chemical Engineering Progress* 63, no. 5 (1967): 26–29.

55. For example, of the nearly one million engineers working in the United States in 1966, only 4 percent worked at universities, while industry and the federal government employed the vast majority (80 percent and 15 percent respectively). Data from National Science Foundation, *Employment of Scientists and Engineers in the United States, 1950–1966*. See also, Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008), esp. chapters 4–6.

56. Quotes from chapter 16 of Whyte, *The Organization Man*.

57. David Kaiser, "The Postwar Suburbanization of American Physics," *American Quarterly* 56, no. 4 (2004): 851–888; also, David Kaiser, *How the Hippies Saved Physics: Science, Counterculture, and the Quantum Revival* (New York: Norton, 2011).

58. *IEEE Spectrum*, 5, no. 3 (1968): 199.

59. *IEEE Spectrum*, 4, no. 6 (1967): 37.

60. *Mechanical Engineer*, 89, no. 2 (1967): 147, emphasis in original.

61. *IEEE Spectrum*, 1, no. 3 (1964): 270.

62. *IEEE Spectrum*, 2, no. 3 (1965): 296.

63. *IEEE Spectrum*, 3, no. 5 (1966): 119.

64. These appeared in the July 1965 and September 1965 issues of *IEEE Spectrum*, pages 141 and 129 respectively.

65. *IEEE Spectrum*, 4, no. 1 (1967): 121.

66. *IEEE Spectrum*, 3, no. 2 (1966): 145.

67. Rob Pope, *Creativity: Theory, History, and Practice* (New York: Routledge, 2005); Nadine Weidman, "Between the Counterculture and the Corporation: Abraham Maslow and Humanistic Psychology in the 1960s," in *Groovy Science: Knowledge, Innovation, and American Counterculture*, ed. David Kaiser and W. Patrick McCray (Chicago: University of Chicago Press, 2016), 109–141, doi:10.7208/chicago/9780226373072.003.0004.

68. Jamie Cohen-Cole, "The Creative American: Cold War Salons, Social Science, and the Cure for Modern Society," *Isis* 100, no. 2 (2009): 219–262, doi:10.1086/599554.

69. Taher A. Razik, *Bibliography of Creativity Studies and Related Areas* (Buffalo: State University of New York, 1965).

70. Published as Calvin W. Taylor and Frank Barron, eds., *Scientific Creativity: Its Recognition and Development* (New York: Wiley, 1963).

71. Daniel S. Greenberg, "Let's Hold a Conference: Herewith an Imaginary Dialog between the Collector and His Quarry," *Science* 144, no. 3623 (1964): 1204–1205.

72. Quotes from Susan Sontag, "The One Culture and the New Sensibility," in *Against Interpretation and other Essays* (New York: Picador, 1966), 293–304.

CHAPTER 3

1. "I Believed in the Art World as the Only Serious World that Existed," Billy Klüver, interview by Edward Shanken, in *Artists as Inventors, Inventors as Artists*, ed. Dieter Daniels and Barbara U. Schmidt (Berlin: Hatje Cantz, 2008), 176–181.

2. Information on and reaction to the 1965 blackout comes from several sources, including David E. Nye, *When the Lights Went Out: A History of Blackouts in America* (Cambridge, MA: MIT Press, 2010), a special November 19, 1965 issue of *Life* devoted to the event, and A. M. Rosenthal and Arthur Gelb, eds., *The Night the Lights Went Out* (New York: Signet, 1965).

3. "Notes and Comment," *New Yorker*, November 20, 1965, 43–47, 44.

4. Description is from Calvin Tomkins's notes; IV. C. 20, CT/MoMA.

5. The text of Klüver's January 28, 1966 talk can be found in a number of locations, including files for 1966 in Experiments in Art and Technology records, EAT/AAA.

6. Grace Glueck, "Scientist Brings Art to His Work: Billy Klüver's Skill Goes into Friends' Creations," *New York Times*, December 17, 1965, https://nyti.ms/1HhLLPV; David Bourdon, "Sculptures in Motion," *Life,* August 12, 1966, 40–49, 47.

7. Before his death in 2004, Klüver prepared several autobiographical essays that accompanied his writings. A copy of this document, titled "Art and Technology: Collected Writings of Billy Klüver," was kindly provided to me by Julie Martin. Many of these essays were later published (in Swedish) in a book titled *Teknologi För Livet: Om Experiments in Art and Technology* (Stockholm: Schultz Förlag, 2004). As I'm working with the original English versions, my references to Klüver's essays are referred to here as "BK/CW."

8. Fredrik Gustafsson, "Swedish Cinema of the 1940s, a New Wave," in *A Companion to Nordic Cinema*, ed. Mette Hjort and Ursula Lindqvist (New York: Wiley Blackwell, 2016), 313–332, doi:10.1002/9781118475300.ch14.

9. "Early Years: From Monaco to the United States," in BK/CW.

10. "Early Years: From Monaco to the United States," in BK/CW. Alfvén's 1966 book *Sagan om den stora Datamaskinen* appeared under the pseudonym Olof Johannesson. Published in English two years later as *The Tale of the Big Computer*, it described a future society where all aspects of life are controlled by computers.

11. Norma Loewen, "Experiments in Art and Technology: A Descriptive History of the Organization" (PhD diss., New York University, 1975), 13, ProQuest (287918505).

12. These devices, called backward-wave oscillators, had been developed at the Paris-based company where Klüver had briefly worked. His doctoral dissertation was completed as Johan Wilhelm Klüver, "Backward-Wave Interaction in Beam-Type Magnetron Amplifiers" (PhD diss., Department of Electrical Engineering, University of California at Berkeley, 1957), ProQuest (302015270).

13. Scott MacDonald, *Art in Cinema: Documents toward a History of a Film Society* (Philadelphia: Temple University Press, 2006).

14. "Notes on 'Fragment on Man and the System,'" BK/CW.

15. Billy Klüver, "Fragment on Man and the System," *The Hasty Papers* 1, no. 1 (1960): 45; also, Alfred Leslie, *The Hasty Papers, special millennium ed.* (Austin: Host, 1999).

16. Job offer letters dated 1957 and 1958; BK/JM.

17. A. Michael Noll, "Bell System R&D Activities: The Impact of Divestiture," *Telecommunications Policy* 11, no. 2 (1987): 161–178, doi:10.1016/0308-5961(87)90024-3.

18. A. Michael Noll, "Memories: A Personal History of Bell Telephone Laboratories" (working paper, Quello Center, Michigan State University, East Lansing, 2015), 1, http://noll.uscannenberg.org/. Drafts of Noll's recollections and other materials from him at the Huntington Library (AMN/HL) are a limited but useful source. Many histories of Bell Labs have been written, including Jon

Gertner, *The Idea Factory: Bell Labs and the Great Age of American Innovation* (New York: Penguin, 2012).

19. Unfortunately, despite his involvement in several high-profile projects and his fantastically diverse career, the archival record for Pierce is frustratingly scant. A. Michael Noll donated some materials to the Huntington Library which I consulted (JP/HL), and there is a similarly small collection at Stanford University's archive.

20. Undated statement from John R. Pierce, likely mid-1967; Folder 18, Box 4, EAT/GRI; a similar version appears in *E.A.T. News* 1, no. 3 (November 1, 1967); Box 138, EAT/GRI. See also, Jeff Gates, "Computers and Art," *Eye Level* (blog), Smithsonian American Art Museum, March 23, 2015, https://americanart.si.edu/blog-post/445/computers-and-art.

21. Kathy Battista, "E.A.T.—The Spirit of Collaboration," in *E.A.T.: Experiments in Art and Technology*, ed. Sabine Breitwieser (Cologne: Walther König, 2016), 9.

22. A recent look at how cosmological research was situated in the context of both corporate as well as national security interests is Kendrick Oliver, "'The Lucky Start Toward Today's Cosmology'? Serendipity, the 'Big Bang' Theory, and the Science of Radio Noise in Cold War America," *Historical Studies in the Natural Sciences* 49, no. 2 (2019): 151–193, doi:10.1525/hsns.2019.49.2.151.

23. J. R. Pierce, "Portrait of the Machine as a Young Artist," *Playboy* 12, no. 6 (June 1965): 148–150, 182, 184.

24. Noll presented his work in a psychological journal as "Human or Machine: A Subjective Comparison of Piet Mondrian's 'Composition with Lines' and a Computer-Generated Picture," *Psychological Record* 16, no. 1 (1966): 1–10, doi:10.1007/BF03393635.

25. Jud Yalkut, "Art and Technology of Nam June Paik," *Arts Magazine*, April 1968, 51.

26. Paik's "sonata" was prepared sometime in 1965; from materials in the Nam June Paik collection (NJK/AAA), published in *We Are in Open Circuits: Writings by Nam June Paik*, ed. John G. Harnhardt, Gregory Zinman, and Edith Decker-Phillips (Cambridge, MA: MIT Press, 2019), 100–114.

27. December 15, 1964 letter from Klüver to Pierce; BK/JM, emphasis in original.

28. Comment from Klüver's personal recollections, circa 2000; BK/CW.

29. John Canaday, "Machine Tries to Die for Its Art," *New York Times*, March 18, 1960, https://nyti.ms/1XTOTFN.

30. For full description of *Homage to New York* see MoMA's March 18, 1960 press release, https://www.moma.org/momaorg/shared/pdfs/docs/press_archives/2634/releases/MOMA_1960_0033_27.pdf. A fragment of Tinguely's piece was secured by MoMA staff and later exhibited at the 2017 exhibition *Robert Rauschenberg: Among Friends*.

31. Harold Hodges, interview by Cameron Vanderscoff, November 9, 2014, transcript, Robert Rauschenberg Oral History Project, Columbia Center for Oral History Research, New York, http://www.rauschenbergfoundation.org/artist/oral-history/harold-hodges.

32. Billy Klüver, interview by Calvin Tomkins, January 18, 1961, IV. C. 20, CT/MoMA.

33. Canaday, "Machine Tries to Die for Its Art."

34. John Canaday, "Odd Kind of Art," *New York Times*, March 27, 1960, https://nyti.ms/1PqXAo3.

35. "Tinguely's Contraption," *Nation*, March 26, 1960, 267.

36. Klüver's essay was reprinted in several places in the 1960s; it first appeared in the short-lived publication *ZERO 1* (1961): 168–171.

37. Hultén's show was billed as *Bewogen Beweging* in Amsterdam and in Stockholm as *Rörelse I Konsten*.

38. See, for example, George Rickey, "The Kinetic International," *Arts Magazine,* September 1961, 16–21.

39. Patrik Andersson, “Rörelse i konsten: The Art of Re-Assemblage,” *Konsthistorisk tidskrift/Journal of Art History* 78, no. 4 (2009): 178–192, doi:10.1080/00233600903461396; this account also draws on Klüver’s own recollections, CW/BK.

40. Among the many excellent descriptions of pop art is chapter 3 of Thomas Crow, *The Rise of the Sixties* (New Haven: Yale University Press, 1996).

41. Billy Klüver, interview by Anne Collins Goodyear, January 13, 1999. Duchamp’s influences on Klüver are presented in Goodyear’s exhaustively researched study “The Relationship of Art to Science and Technology in the United States, 1957–1971: Five Case Studies” (PhD diss., University of Texas at Austin, 2002), 207–211, ProQuest (305503573). For a broader sense of Duchamp’s interest in science and technology, see Linda D. Henderson’s *Duchamp in Context: Science and Technology in the* Large Glass *and Related Works* (Princeton: Princeton University Press, 1998), while Calvin Tomkin’s *Duchamp: A Biography* (New York: Henry Holt, 1996) is an excellent, accessible introduction to the artist.

42. Robert Lebel, *Marcel Duchamp*, trans. George H. Hamilton (New York: Paragraphic, 1959), 29.

43. Klüver in Anice Kandell, ed., *Art 1963: A New Vocabulary* (Philadelphia: Fine Arts Committee of the Arts Council of the Young Men’s and Young Women’s Hebrew Association, 1962), 3.

44. Klüver quoted in Douglas Davis, *Art and the Future: A History/Prophecy of the Collaboration Between Science, Technology, and Art* (New York: Praeger, 1973), 140.

45. Billy Klüver, interview by Anne Collins Goodyear, January 13, 1999.

46. Billy Klüver, “The Arts and Science Club” (unpublished manuscript, September 28, 1962); CW/BK.

47. Jean M. White, “Eruption of Pop Art Slated for this Week,” *Washington Post*, April 14, 1963.

48. Billy Klüver “Happenings,” *Konstrevy* 39 (1962) and “Bakelsen som Kunst (Pastry as Art),” *Vi* (Stockholm) 51, no. 9 (1964): 11–13. Information on Adorno’s involvement in the pop art world comes from John Anderson, “What Happened in Washington,” *Washington City Paper*, March 12, 2012, http://www.washingtoncitypaper.com/arts/museums-galleries/blog/13077263/what-happened-in-washington.

49. Klüver’s recollections come from Billy Klüver and Julie Martin, “Four Difficult Pieces,” *Art in America* 79, no. 7 (1991): 80–99, 138. A modified version of this essay, with some additional information, appears as “Working with Rauschenberg,” in *Robert Rauschenberg: A Retrospective*, ed. Walter Hopps and Susan Davidson (New York: Guggenheim Museum, 1997), 310–327.

50. Robert Rauschenberg, quoted in Billy Klüver, *Record of Interviews with Artists Participating in the “Popular Image” Exhibition* (Washington, DC: Washington Gallery of Art, 1963).

51. Barbara Rose, *Rauschenberg: An Interview with Robert Rauschenberg* (New York: Vintage, 1987), 67.

52. Klüver and Martin, “Four Difficult Pieces.”

53. Sally Banes, *Democracy’s Body: Judson Dance Theatre, 1962–1964* (Ann Arbor: University of Michigan Press, 1983) as well as Ana Janevski and Thomas J. Lax, eds., *Judson Dance Theatre: The Work Is Never Done* (New York: Museum of Modern Art, 2018).

54. Allen Hughes reviewed the show twice: “Dance: Created on Stage,” *New York Times*, July 24, 1965, https://nyti.ms/1MNxflg, and “Leaps and Credenzas,” *New York Times*, August 1, 1965, https://nyti.ms/1iHQm28.

55. Signaling a take on Susan Sontag’s “New Sensibility,” this article was published as Barbara Rose and Irving Sandler, “Sensibility of the Sixties,” *Art in America* 55, no. 1 (1967): 44–57.

56. Rose and Sandler, “Sensibility of the Sixties,” 48, 44, and 49.

57. Allan Kaprow, “Should the Artist Become a Man of the World?,” *Art News* 63, no. 6 (1964): 34–37, 58–59.

58. See essays in James Elkin's edited collection *Artists with PhDs: On the New Doctoral Degree in Studio Art* (Washington, DC: New Academia, 2014).

59. Kaprow, "Should the Artist Become a Man of the World?," 59.

60. Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago: University of Chicago Press, 2008).

61. Caroline A. Jones, *Machine in the Studio: Constructing the Postwar American Artist* (Chicago: University of Chicago Press, 1998).

62. Anna Dezeuze, "The 1960s: A Decade out of Bounds," in *A Companion to Contemporary Art Since 1945,* ed. Amelia Jones (Malden, MA: Blackwell, 2006), 38–59.

63. Quote from Nan Piene, "Editorial: Patronage and Democracy," *Art in America* 55, no. 2 (1967): 1. This piece appeared in an issue devoted to the question of artists and patronage.

64. Jay Jacobs, "What the Federal Arts Program Really Means," *Art in America* 55, no. 2 (1967): 25–26, 28–29.

65. William Hackman, *Out of Sight: The Los Angeles Art Scene of the Sixties* (New York: Other, 2015).

66. Amy Newman, *Challenging Art: Artforum, 1962–1974* (New York: Soho Press, 2000).

67. Rose and Sandler, "Sensibility of the Sixties," 47, 49.

68. Kaprow, "Should the Artist Become a Man of the World?," 59.

69. Barbara Rose, "Shall We Have a Renaissance?," *Art in America* 55, no. 2 (1967): 30–39.

70. Howard Brick, *Age of Contradiction: American Thought and Culture in the 1960s* (Ithaca: Cornell University Press, 1998). Although the term "postindustrial society" is most commonly associated with Daniel Bell's 1973 book *The Coming of Post-Industrial Society*, scholars began using it as early as the late 1950s.

71. Quote from Alain Touraine, *The Post-Industrial Society*, trans. Leonard Mayhew (New York: Random House, 1973), 5. See also, Howard Brick, "Optimism of the Mind: Imagining Postindustrial Society in the 1960s and 1970s," *American Quarterly* 44, no. 3 (1992): 348–380, doi:10.2307/2712981.

CHAPTER 4

1. Quote from Herb A. Schneider, "A View from Central" (unpublished manuscript, October 1966); Folder 1, Box 4, EAT/GRI.

2. May 27 and June 18, 1980 letters between Klüver and Tomkins; Folder 50, Box 120, EAT/GRI.

3. Calvin Tomkins, "Onward and Upward with the Arts: E.A.T.," *New Yorker*, October 3, 1970, 83–133.

4. The book project is discussed in a October 29, 1966 letter from Carroll Bowen, of the MIT Press, to Klüver and subsequent correspondence; Folders 21 and 22, Box 1, EAT/GRI. The rapid pace of E.A.T.'s growth helped put the project into hibernation. In the early 1970s, Harriet DeLong revived it as an edited book, corresponding with at least two different presses. In a bizarre turn of events (terrifying to this author), the manuscript, or at least parts of it, were lost in mail exchanges between DeLong and the MIT Press. Consequently, her book never materialized. However, a draft is preserved in the archives of the Getty Research Institute (Box 1, EAT/GRI), which is replete with valuable primary source material. Hereafter, I refer to this as "DeLong" and, where possible, note page numbers as they appear in the GRI material.

5. I've especially relied on two doctoral dissertations that examine *9 Evenings*. One is Norma Loewen's "Experiments in Art and Technology: A Descriptive History of the Organization" (PhD diss., New York University, 1975), ProQuest (287918505), which was based on her access to participants and original documents (some of which have since disappeared). The other is Anne Collins Goodyear's much more comprehensive analysis, "The Relationship of Art to Science and

Technology in the United States, 1957–1971: Five Case Studies" (PhD diss., University of Texas at Austin, 2002), ProQuest (305503573). In addition, several curators have revisited *9 Evenings,* such as Catherine Morris's exhibition at MIT's LIST Visual Arts Center; see Catherine Morris, ed., *9 Evenings Reconsidered: Art, Theatre, and Engineering, 1966* (Cambridge, MA: MIT List Visual Arts Center, 2006).

6. Frank Rose, "The Big Bang of Art and Tech in New York," *New York Times*, November 6, 2015, https://nyti.ms/1WD280j.

7. Billy Klüver, "Theatre and Engineering: An Experiment—2. Notes by an Engineer," *Artforum* 5, no. 6 (1967): 31–33.

8. Herb Schneider, "A View from Central," (unpublished manuscript, October 1966); Folder 1, Box 4, EAT/GRI.

9. Billy Klüver, "Outline for 'Engineering in Art,'" October 1965; September 29, 1969 letter from Bruce Strasser to Klüver; both BK/JM. Also, additional quotes from manuscript—now presumably lost—appear in Loewen's "Experiments in Art and Technology," 40–43.

10. March 7, 1966 letter from Klüver to Walter Gutman, Document 3 in DeLong; Box 1, EAT/GRI.

11. Hay's recollections are in notes about *9 Evenings* collected throughout 1966 by dancer Simone Forti. Titled "A View of *9 Evenings*: Theatre and Engineering," they are archived in Box 1, EAT/GRI.

12. DeLong, 2.6; Box 1, EAT/GRI. Klüver's "Theatre and Engineering" tells a similar variation.

13. These materials formed the basis for an article Forti published under her married name: Simone Whitman, "Theatre and Engineering: An Experiment 1. Notes by a Participant." *Artforum* 5, no. 6 (1967): 26–30.

14. Forti, "A View of *9 Evenings*," 2.

15. Ibid., 7–8.

16. Overall, Klüver estimated that the engineers volunteered some 8,500 hours in all; a breakdown of this is in DeLong, 17.8–9; Box 1, EAT/GRI.

17. Quote comes from transcript of E.A.T.'s first open-house meeting, November 20, 1966; DeLong, 21.5; Box 1, EAT/GRI.

18. Klüver, quoted in Loewen, "Experiments in Art and Technology," 55.

19. Schneider, "A View from Central."

20. From a series of questionnaires filled out by participants after *9 Evenings*; DeLong, Chapter 17; Box 1, EAT/GRI.

21. Schneider, "A View from Central."

22. Klüver's public relations instructions given in August 1966; DeLong, 2.16; Box 1, EAT/GRI.

23. Klüver, "Theatre and Engineering," 31.

24. Billy Klüver, "Remarks to the Press," September 29, 1966; EAT/AAA.

25. May 11, 1966 letter from Franklin Konigsberg (who served as the group's legal advisor) to Knut Wiggen; listed as Document 2 in DeLong; final cost estimates appear at the end of DeLong's manuscript; Box 1, EAT/GRI.

26. On September 20, 1966, David Rockefeller gave a speech entitled "Culture and the Corporation," which was the founding address of the Business Committee for the Arts; David Rockefeller, "Culture and the Corporation" (speech, 50th Anniversary Conference of the National Industrial Conference Board [now known as The Conference Board], New York, September 20, 1966), https://www.americansforthearts.org/sites/default/files/pdf/2016/events/rockefeller/David%20Rockefeller%20speech%201966.pdf?utm_source=MagnetMail&utm_medium=email&utm_term=jgaines@artsusa.org&utm_content=BCAnoteworthy_11_2_16&utm_campaign=BCA%20Noteworthy%20November%202016.

27. March 24, 1966 letter from Klüver to Boyd Compton; listed as Document 2 in DeLong, Box 1, EAT/GRI.

28. August 24, 1966 letter from Scheweber to Konigsberg; Loewen, "Experiments in Art and Technology," 67.

29. March 7, 1966 letter from Klüver to Gutman; listed as Document 3 in DeLong, Box 1, EAT/GRI.

30. April 8, 1966 letter from Klüver to Pierce; 1966 files, EAT/AAA.

31. Billy Klüver and Julie Martin, "Working with Rauschenberg," in *Robert Rauschenberg: A Retrospective*, ed. Walter Hopps and Susan Davidson (New York: Guggenheim Museum, 1997), 314–315. "Mar. 11—Notes from Meeting" from Klüver's diary and notes; Box 2, EAT/GRI; statement by Rauschenberg in DeLong, 2.10; Box 1, EAT/GRI.

32. Klüver's views come from an undated manuscript he wrote, probably in April 1966 that is quoted in Loewen, "Experiments in Art and Technology," 57–58; statements by the Swedes are in DeLong, 2.7 to 2.10, Box 1, EAT/GRI.

33. The initial descriptions are in a July 23, 1966 document that Klüver sent to Stockholm; Document 5 in DeLong, Box 1, EAT/GRI.

34. Forti, "A View of *9 Evenings*," 15.

35. Telegrams described in DeLong, 2.14; Box 1, EAT/GRI.

36. Barbara Rose's chapter "The Armory Show: Success by Scandal" in her book *American Art Since 1900: A Critical History* (New York: Praeger, 1967) gives an especially interesting perspective given that Rose also wrote extensively and (often) positively about the art-and-technology movement.

37. The article featuring Klüver appeared as David Bourdon, "A Good Janitor Becomes as Important as a Curator," *Life*, August 12, 1966, 45–47, 49, along with a longer piece that focused on kinetic art.

38. Forti, "A View of *9 Evenings*," 15.

39. Details on the Armory space from "The Armory," on the 69th Regiment's official website, accessed October 15, 2017, http://www.sixtyninth.net/armory.html.

40. Brian O'Doherty, "New York: 9 Armored Nights" *Art and Artists* 1, no. 9 (1966): 14–17.

41. Forti, "A View of *9 Evenings*," 15.

42. DeLong, 17.4; EAT/GRI.

43. Klüver, "Theatre and Engineering," 33.

44. Lucy Lippard, "Total Theatre?," *Art International* 11, no. 1 (1967): 39; Gloria Bryant, "The Switched-On Theater," *Reporter* (November/December 1966): 11–16.

45. Between 1960 and 1967, AT&T's defense contracts totaled some $4 billion; Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993), 253.

46. Klüver's August 23, 1966 memo to Ruder and Finn is in DeLong, 2.7; EAT/GRI.

47. March 7, 1966 letter from Klüver to Gutman; listed as Document 3 in DeLong; EAT/GRI.

48. January 31, 1973 statement by John Pierce; DeLong, 16.25; EAT/GRI.

49. Hay's plans are presented in the original 1966 program for *9 Evenings: Theatre and Engineering* and also reproduced in Morris, *9 Evenings Reconsidered*; see also Alex Hay, interview by Alessandra Nicifero, December 8, 2014, transcript, Robert Rauschenberg Oral History Project, Columbia Center for Oral History Research, New York, https://www.rauschenbergfoundation.org/artist/oral-history/alex-hay.

50. Art historian Clarisse Bardiot discusses this as part of her exhaustive online multimedia exploration of *9 Evenings*, Daniel Langlois Foundation for Art, Science, and Technology official website, http://www.fondation-langlois.org/html/e/page.php?NumPage=572; text copies, which Bardiot graciously provided, are in the author's collection. Hereafter cited as Bardiot, *9 Evenings*.

51. Hay's *Grass Field* is described and documented in Part 6 of DeLong; Box 1, EAT/GRI.

52. Alex Hay, interview by Simone Forti, September 17, 1966, DeLong 6.4; Box 1, EAT/GRI.

53. L. J. ("Robby") Robinson, "Preparations for Alex Hay's Piece," DeLong, 6.6; Box 1, EAT/GRI.

54. Ibid.

55. Lippard, "Total Theatre?," 39–44.

56. John T. Correll, "Igloo White," *Air Force Magazine*, November 2004, 56–61, http://www.airforcemag.com/MagazineArchive/Pages/2004/November%202004/1104igloo.aspx; Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America* (Cambridge, MA: MIT Press, 1996), 3–5.

57. Heilos's recollections are in DeLong, 8.8; Box 1, EAT/GRI; while their phosphor discovery is in J. D. McGee and L. J. Heilos, "Visual Display of Infrared Laser Output on Thermographic Phosphor Screens," *IEEE Journal of Quantum Electronics* 3, no. 1 (1967): 31, doi:10.1109/JQE.1967.1074365.

58. Herb Schneider, "A Systems Approach to Robert Rauschenberg's *Open Score*," DeLong, 8.15; Box 1, EAT/GRI.

59. Fred D. Waldhauer, interview by Julie Martin, August 4, 1991, transcript in the author's files.

60. "Technology and the Arts," *Reporter*, April 1966, 16–19.

61. Fred D. Waldhauer, "Proportional Control System for the Festival of Art and Engineering," (unpublished manuscript, September 19, 1966); Folder 15, Box 2, EAT/GRI.

62. Dave Tomkins, *How to Wreck a Nice Beach: The Vocoder from World War Two to Hip-Hop* (New York: Stop Smiling, 2011).

63. Bardiot, *9 Evenings*; Robert Kieronski, "Vochrome-Vochomator," May 6, 1966 technical memorandum, DeLong, 9.15; Box 1, EAT/GRI.

64. Herb Schneider, "Proportional Control Device," emphasis in original, DeLong, 9.8; Box 1, EAT/GRI.

65. Peter Hirsch, "The Doppler Sonar," undated essay, DeLong, 12.9; Box 1, EAT/GRI.

66. Per Biorn, interview by Julie Martin, August 25, 2004; transcript in the author's files.

67. Dick Wolff, "Response to Questionnaire," undated, but likely late 1966; Folder 16, Box 2, EAT/GRI.

68. On Cage and engineering, see Richard H. Brown, "The Spirit inside Each Object: John Cage, Oskar Fischinger, and the 'Future' of Music," *Journal of the Society for American Music* 6, no. 1 (2012): 83–113, doi:10.1017/S1752196311000411.

69. Kris Paulsen, *Here/There: Telepresence, Touch, and Art at the Interface* (Cambridge, MA: MIT Press, 2017).

70. Claude S. Fischer, *America Calling: A Social History of the Telephone to 1940* (Berkeley: University of California Press, 1992).

71. April 8, 1966 letter from Klüver to Pierce; 1966 files, EAT/AAA.

72. Dick Higgins, "Intermedia," *Leonardo* 34, no. 1 (2001): 49–54, https://www.muse.jhu.edu/article/19618; originally published in *Something Else Newsletter* 1, no. 1 (1966).

73. From Fahlström's comments on his piece in the original *9 Evenings* program.

74. Billy Klüver, "To the Engineers," September 16, 1966 memo; Folder 12, Box 4, EAT/GRI.

75. Agatha Hughes and Thomas Hughes, eds., *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After* (Cambridge, MA: MIT Press, 2000); as well as Thomas Hughes, *Rescuing Prometheus: Four Monumental Projects that Changed the Modern World* (New York: Vintage, 1998).

76. Alternatively, the equipment was sometimes also called the "Theatre Environmental Modular Electronic," or THEME. Klüver's comment and description comes from a memo dated July 23,

1966, listed as Document 5 in DeLong; Box 1, EAT/GRI. For a more technical description see, Nat Snyderman, “The New Imp Theatre,” *Electronic News,* August 22, 1966, 24.

77. “Technology for Art’s Sake,” September 14, 1966 press release; EAT/AAA; John Gruen, “Art Meets Technology,” *World Journal Tribune*, October 2, 1966, 22, 28; copy in DeLong, Box 1, EAT/GRI.

78. The original request as well as the temporary radio station license, appear as Document 8 in DeLong; Box 1, EAT/GRI.

79. Klüver quoted in Forti, “A View of *9 Evenings*,” 14.

80. August 23, 1966 memo from Klüver to Ruder and Finn, DeLong, 2.17; Box 1, EAT/GRI.

81. March 1973 statement by Tudor; DeLong, 16.0; Box 1, EAT/GRI.

82. Clarisse Bardiot, “The Diagrams of *9 Evenings,*” 45–53, as well as interview with Schneider; both in *9 Evenings Reconsidered: Art, Theatre, and Engineering, 1966*, ed. Catherine Morris (Cambridge, MA: MIT List Visual Arts Center, 2006).

83. Herb Schneider, “A Glimpse or More at Some Technical Aspects Not Seen by the Third Partner of *Nine Evenings*—The Public” (unpublished manuscript, October 1966); Folder 1, Box 4 EAT/GRI.

84. Herb Schneider, “*Nine Evenings*—A View From Central,” (unpublished manuscript, October 1966); Folder 1, Box 4 EAT/GRI.

85. Schneider, “A Glimpse or More at Some Technical Aspects Not Seen by the Third Partner of *Nine Evenings*.”

86. Schneider, “*Nine Evenings*.”

87. Forti, “A View of *9 Evenings*,” 21. Robby Robinson, “At the Armory,” DeLong, 19.3; Box 1, EAT/GRI.

88. “Technical Equipment, *9 Evenings*,” undated memo, ca. November 1966; Folder 15, Box 2, EAT/GRI.

89. Publicity materials for *9 Evenings* can be found in the “1966” folder of EAT/AAA as well as Folders 7–10, Box 3, EAT/GRI.

90. August and September 1966 press releases; EAT/AAA.

91. Quotes come from September 28, 1966 press release and Klüver’s remarks on September 29, 1966; EAT/AAA.

92. Gruen, “Art Meets Technology”; copy in DeLong, Box 1, EAT/GRI.

93. A version of this is in Box 3, EAT/GRI; images also can be seen at “9 Evenings: Theatre and Engineering,” *Monoskop*, accessed November 22, 2019, https://monoskop.org/9_Evenings:_Theatre_and_Engineering.

94. Richard Kostelanetz, “The Artist as Playwright and Engineer,” *New York Times Magazine*, October 9, 1966, 32–34, 114, 119–121, 124, https://nyti.ms/1iYk2bh.

95. Forti, “A View of *9 Evenings*,” 19.

96. Patrick O’Connor, “‘Theatre, Engineering’ Less than Pleasing,” *Jersey Journal*, October 17, 1966; Grace Glueck, “Arts and Engineering Mixing It Up at the Armory,” *New York Times*, October 14, 1966, https://nyti.ms/1PF7enh.

97. Forti, “A View of *9 Evenings*,” 21.

CHAPTER 5

1. From November 29, 1967 remarks to North Carolina State Art Society; EAT/AAA.

2. Clive Barnes, “Dance: Village Disaster,” *New York Times*, January 11, 1965, https://nyti.ms/1RSJY4u.

3. Quotes from two articles Barnes wrote for the *New York Times*: “Dance or Something at the Armory,” October 15, 1966, https://nyti.ms/1N0EHJQ; and “Happening: Ineffable Night at Armory,” October 17, 1966, https://nyti.ms/1N0G2R9.

4. Robby Robinson, "What Really Happened at the Armory," unpublished manuscript, likely November 1966; Folder 17, Box 3, EAT/GRI.

5. Quotes come from a draft, in Box 2, EAT/GRI that Klüver wrote in November 1966; this was later was published as "Theatre and Engineering: An Experiment—2. Notes by an Engineer" *Artforum* 5, no. 6 (1967): 31–33.

6. Nat Snyderman, "Engineering Goes to the Theatre," *Electronic News*, October 17, 1966, 6; John J. O'Connor, "The Gallery: Art Meets Science," *Wall Street Journal*, October 21, 1966.

7. Jill Johnston, "Post-Mortem," *Village Voice*, December 15, 1966.

8. Herb Schneider, "Drafts and Notes," undated but likely late October 1966; Folder 1, Box 4, E.A.T. /GRI.

9. Norma Loewen, "Experiments in Art and Technology: A Descriptive History of the Organization" (PhD diss., New York University, 1975), 90, ProQuest (287918505); Billy Klüver and Julie Martin, "Working with Rauschenberg," in *Robert Rauschenberg: A Retrospective*, ed. Walter Hopps and Susan Davidson (New York: Guggenheim Museum, 1997), 316–317.

10. E.A.T.'s certificate of incorporation is provided as Document XII in DeLong, Box 1, EAT/GRI; Klüver in *E.A.T. News* 1, no. 1 (January 1, 1967): 2; EAT/AAA.

11. Max V. Mathews, untitled and undated essay, likely mid-1967; EAT/AAA.

12. February 27, 1967 letter from Walter Gutman to Klüver, DeLong 16.20; Box 1, EAT/GRI.

13. Billy Klüver, "To the Engineers Who Participated in *Nine Evenings*," undated memo but likely late October 1966; Folder 12, Box 4, EAT/GRI.

14. "Meeting Invitation," November 1966; Folder 12, Box 4, EAT/GRI.

15. Brian O'Doherty's quotes and other material in this section come from DeLong, section 21, titled "The 10th Evening"; Box 1, EAT/GRI; also, descriptions of the event in Loewen, "Experiments in Art and Technology," 92–94, and materials in Folder 25, Box 9, EAT/GRI.

16. From Schneider's notes for the meeting; Folder 25, Box 9, EAT/GRI.

17. Melissa Ho, ed., *Artists Respond: American Art and the Vietnam War, 1965–1975* (Princeton: Princeton University Press, 2019), 66.

18. Schneemann and Flynn's recollections in *E.A.T. News*, 1, no. 2 (June 1, 1967): 15–18

19. Erica Levin, "Sounding *Snows*: Bodily Static and the Politics of Visibility during the Vietnam War," in *Hybrid Practices: Art in Collaboration with Science and Technology in the Long 1960s,* ed. David Cateforis, Steven Duval, and Shepherd Steiner (Berkeley: University of California Press, 2018), 113–124.

20. *E.A.T. News* 1, no. 2 (June 1, 1967): 17.

21. March 17, 1967 statement from Klüver and Rauschenberg; Folder 3, Box 3; Undated, handwritten statement by Rauschenberg; Folder 18, Box 4, both EAT/GRI.

22. *E.A.T. News* 1, no. 1 (January 1, 1967): 17.

23. Included with March 17, 1967 letter from Klüver to "Friends of E.A.T."; Folder 3, Box 3, EAT/GRI.

24. Undated and untitled draft essay, likely March 17, 1967 letter from Klüver to "Friends of E.A.T."; Folder 3, Box 3, EAT/GRI.

25. Douglas M. Davis, "The New Combine," *Art in America* 56, no. 1 (1968): 37.

26. Roderick Nordell, "'We're Not Interested in Art,' the Man Said," *Christian Science Monitor*, May 13, 1968.

27. July 17, 1967 letter from Klüver to John G. Powers; Folder 18, Box 4, EAT/GRI; the second amount as well as a list of donations made in 1967 comes from 1968 budget documents in EAT/AAA.

28. Grace Glueck, "Hot Off the Drawing Board," *New York Times*, February 26, 1967, https://nyti.ms/1kdTJiw.

29. For example, Gloria Bryant's "What's Happening! Bell Labs Engineers Go Arty," *Western Electric* 19, no. 1 (1967): 14–21.

30. Klüver to IEEE described in Loewen, "Experiments in Art and Technology," 104–105; membership numbers in *E.A.T. News* 2, no. 1 (March 18, 1968): 18. Eventually, E.A.T. would report as many as 2,000 artists as members and some 4,000 people overall; *E.A.T. Operations and Information* 1 (November 1, 1968): 5.

31. January 9, 1967 letter from Neil Nathan to Klüver; Folder 3, Box 3, EAT/GRI.

32. Undated letter, likely March 1967, from Klüver to W. Howard Adams; Folder 18, Box 4, EAT/GRI.

33. Forkner's application to E.A.T., along with scores of others from engineers and artists, are in Boxes 7 and 8 of EAT/GRI.

34. March 10, 1970 conversation between John Forkner and Barbara Rose; Cassette 42, Box 10, Barbara Rose papers (accession no. 930100), Getty Research Institute (BR/GRI).

35. Quotes in this section are all from Billy Klüver, "Interface: Artist/Engineer" (lecture, Massachusetts Institute of Technology, Cambridge, MA, April 21, 1967); EAT/AAA.

36. For how this intersected with engineers' and their education, see Matthew Wisnioski, "'Liberal Education has Failed': Reading Like an Engineer in 1960s America," *Technology and Culture* 50, no. 4 (2009): 753–782.

37. John W. Finney, "Glenn Feels Pilot Can Replace Much of Spaceship Automation," *New York Times*, February 23, 1962, https://nyti.ms/1iH4DvZ.

38. While a crude metric, a Google Ngram with "automation" as the keyword shows a rapid rise of mentions in the 1960s with a peak about 1965. Kennedy's statement about automation comes from a June 7, 1960 address to labor leaders, one of several times he broached the subject on the campaign trail, John F. Kennedy, "Remarks of Senator John F. Kennedy" (speech, AFL–CIO convention, Grand Rapids, MI, June 7, 1960), https://www.jfklibrary.org/asset-viewer/archives/JFKCAMP1960/1030/JFKCAMP1960-1030-036.

39. Quotes and a fuller discussion of the "automation question" are in chapter 8 of Amy Sue Bix, *Inventing Ourselves Out of Jobs: America's Debate over Technological Unemployment, 1929–1981* (Baltimore: Johns Hopkins University Press, 2000).

40. Theodore W. Kheel, interview by Calvin Tomkins, interview notes, February 11, 1970; II.B.11, CT/MoMA.

41. September 20, 1967 memo from Max Mathews to Bell Labs staff; Folder 4, Box 10, TK/CU.

42. *E.A.T. News* 1, no. 2 (June 1, 1967): 4; and Billy Klüver, "Interface: Artist/Engineer"; EAT/AAA.

43. Dominick Dunne's February 1987 profile in *Vanity Fair* offers a characteristically salacious take on Rockefeller: Dominick Dunne, "The Rockefeller and the Ballet Boys," *Vanity Fair*, September 15, 2008, https://www.vanityfair.com/magazine/1987/02/dunne198702.

44. Tomkins, February 11, 1970 interview notes with Kheel; II.B.11, CT/MoMA; Damon Stetson, "Bargaining Body Planned by Kheel," *New York Times*, August 6, 1967, https://nyti.ms/1LBfoeM.

45. Fred Turner, "Romantic Automatism: Art, Technology, and Collaborative Labor in Cold War America." *Journal of Visual Culture* 7, no. 1 (2008): 5–26, doi:10.1177/1470412907087201.

46. A. Michael Noll, "Patterns by 7090," *BTL Technical Memorandum* MM-62-1234-14 (1962). Noll's recollections of computer art experiments at Bell Labs are presented in his essay "Early Digital Computer Art at Bell Telephone Laboratories, Incorporated," *Leonardo* 49, no. 1 (2016): 55–65, https://www.muse.jhu.edu/article/608590. A fuller discussion of Noll's activities is in Zabet Patterson, *Peripheral Vision: Bell Labs, the S-C 4020, and the Origins of Computer Art* (Cambridge, MA: MIT Press, 2015). Some materials related to Noll's experimentation are in his archival collection; AMN/HL.

47. An early recounting of this history is Herbert W. Franke, *Computer Graphics, Computer Art* (London: Phaidon, 1971).

48. This is noted on Noll's personal website, where he discusses computer art, http://noll.uscannenberg.org/.

49. Stuart Preston, "Reputations Made and in Making," *New York Times*, April 18, 1965, https://nyti.ms/1RCm8JS.

50. John Canaday, "Less Art, More Computer, Please," *New York Times*, August 30, 1970, https://nyti.ms/1kxOdYq. For critics' reaction to computer art in general, Grant D. Taylor, *When the Machine Made Art: The Troubled History of Computer Art* (New York: Bloomsbury, 2014).

51. Identified by Klüver and Rauschenberg as their "most important goal" in March 20, 1967 letter to E.A.T.'s board members; Folder 18, Box 4, EAT/GRI.

52. April 20 and May 18, 1967 letters from Klüver to Marian Javits; Folder 4, Box 122, EAT/GRI.

53. June 12 and July 6, 1967 letters from Waldhauer and Klüver to Piore; Folder 18, Box 4, EAT/GRI.

54. December 1, 1967 letter from Klüver to Javits; BK/JM; "Report on E.A.T.," January 10, 1968 report; EAT/AAA.

55. Dated September 9, 1967; Folder 2, Box 128, EAT/GRI.

56. *E.A.T. News* 1, no. 3 (November 1, 1967): 1.

57. For example, "E.A.T. Meeting Minutes," March 6, 1967; Folder 5, Box 128, EAT/GRI.

58. December 26, 1967 letter from Klüver to John de Ménil; Folder 5, Box 122, EAT/GRI.

59. "Proposal for Structuring an Environmental Safety Program for Use by Galleries, Museums, Exhibitions, and Artist/Engineer-Scientist Collaborations," March 15, 1968; EAT/AAA. The larger safety initiative is described in Loewen, "Experiments in Art and Technology," 223–227.

60. Henry R. Lieberman, "Art and Science Proclaim Alliance in Avant-Garde Loft," *New York Times*, October 11, 1967, https://nyti.ms/1QJwffz. Also, "Science for Art's Sake," *Business Week*, October 21, 1967, 56.

61. Jack Mallon, "Art in Our Factories Put on an Even Kheel," *Sunday News*, October 15, 1967; Cathy Aldridge, "Art-Automation Merger, an Historic Experience," *N.Y. Amsterdam News*, October 28, 1967; both in Folder 47, Box 1, TK/CU.

62. John J. O'Connor, "Art & Technology Make It Official," *Wall Street Journal*, October 11, 1967.

63. *E.A.T. News* 1, no. 3 (November 1, 1967): 8–9.

64. This accompanied a short article: "Labor, Industry Encourage Merger of Art, Technology," *AFL-CIO News,* October 21, 1967, 2; copy in October 10, 1967 press release materials; EAT/AAA.

65. Quotes and supporting material come from the October 10, 1967 press release materials; EAT/AAA.

66. Morris's comments are included in the October 10, 1967 press release materials; EAT/AAA. Caroline Jones explores this transformation in her book *The Machine in the Studio: Constructing the Postwar American Artist* (Chicago: University of Chicago Press, 1998).

67. Lieberman, "Art and Science Proclaim Alliance in Avant-Garde Loft."

68. These goals appear in several places, including *E.A.T. News* 1, no. 3 (November 1, 1967): 5, and press materials prepared for the October 1967 gathering; EAT/AAA. Rauschenberg and Klüver also added the wish to offer "original forethought" about technology "instead of a compromise in aftermath." Decades later, some technology policy experts would refer to this as "anticipatory governance"; David H. Guston, "Understanding 'Anticipatory Governance,'" *Social Studies of Science* 44, no. 2 (2014): 218–242, doi:10.1177/0306312713508669.

69. Undated letter, likely March 1967, from Klüver to W. Howard Adams; Folder 18, Box 4, EAT/GRI.

70. The show's catalog, with an introduction by Frank Popper, is *Lumière et Mouvement: Art Cinétique a Paris* (Paris: Musée d'Art Moderne, 1967).

71. Ironically, CBS does not seem to have donated much, if any, money to E.A.T. Instead, Stanton announced his company would support two artist-in-industry positions, an initiative Klüver vainly hoped E.A.T. would be asked to manage; December 1, 1967 letter from Klüver to Marian Javits; BK/JM.

72. "Minutes of Meeting at Loft," November 28, 1967; Folder 10, Box 128, EAT/GRI.

73. Ibid.

74. Lawrence Alloway, "Technology and Art Schools," *Studio International* 175 (April 1968): 184–186.

75. The schedule of lectures as well as transcripts of the actual lectures are collected in Box 28, EAT/GRI.

76. Richard F. Shephard, "'Venice Biennale' Weds Local No. 1," *New York Times*, February 16, 1968, https://nyti.ms/1H9Dnwr; also, February 2, 1968 press package from E.AT.; EAT/AAA.

77. Davis's take as well as interviews with practitioners like Klüver appeared in the journal's January/February 1968 issue.

78. Jack W. Burnham, "Art and Technology," in *Britannica Yearbook of Science and the Future* (Chicago: William Benton, 1973), 344–359.

79. Douglas M. Davis, "Art and Technology: Toward Play," *Art in America* 56, no. 1 (1968): 46–47.

80. Examples include Stanley Klein, "Technology Invades the Arts," *Machine Design* 40, no. 5 (February 29, 1968): 37–46 and A. J. Parisi, "The Kinetic Movement: Technology Paces the Arts," *Product Engineering*, December 2, 1968, 27–35.

81. Info on E.AT. comes from various newsletters and reports, ca. 1967–1968, in the EAT/AAA collection as well as Loewen, "Experiments in Art and Technology."

82. September 25, 1969 letter from Klüver to Julius A. Stratton; Folder 1, Box 42, EAT/GRI.

83. The group was profiled in the September 11, 1967 issue of *Life* magazine; also, Luis Aponte-Parés, "Lessons from *El Barrio*—The East Harlem Real Great Society/Urban Planning Studio: A Puerto Rican Chapter in the Fight for Urban Self-Determination," *New Political Science* 20, no. 4 (1998): 399–420, doi:10.1080/07393149808429838.

84. Billy Klüver, "The Ghetto and the Technical Community: An Opportunity for Challenge," undated, but likely from sometime in the summer of 1968; EAT/AAA. Klüver's proposal, titled "Technology and the Individual" (copy in BK/JM) reflected the larger interest in "humanizing engineers" as described in Matthew Wisnioski, *Engineers for Change: Competing Visions of Technology in 1960s America* (Cambridge, MA: MIT Press, 2012)..

85. Jennifer S. Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America* (Baltimore: Johns Hopkins University Press, 2003).

86. August 27, 1967 letter from Klüver to J. A. Hutcheson; BK/JM.

87. Billy Klüver, "Technology and the Individual: A Proposal for a Research Program," July 10, 1968; BK/JM; also, Carroll Pursell, "The Rise and Fall of the Appropriate Technology Movement in the United States, 1965–1985," *Technology and Culture* 34, no. 3 (1993): 629–637.

88. Douglas M. Davis, "Billy Klüver: The Engineer as a Work of Art," *Art in America* 56, no. 1 (1968): 40.

CHAPTER 6

1. Jack Burnham, *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of this Century* (New York: George Braziller, 1968), 7.

2. There is an extensive literature on the revolts of 1968, broadly speaking; two global perspectives are David Caute, *The Year of Barricades: A Journey through 1968* (New York: Harper and Row, 1988); as well as Carole Fink, Philipp Gassert, and Detlef Junker, eds., *1968: The World Transformed* (New York: Cambridge University Press, 1998), doi:10.1017/CBO9781139052658.

3. November 7 and November 30, 1966 letters between Gyorgy Kepes and Frank Malina; Folder 8, Box 41, FM/LOC.

4. Douglas M. Davis, "Conversations with Gyorgy Kepes, Billy Klüver, and James Seawright," *Art in America* 56, no. 1 (1968): 38–45.

5. Armin Medosch, *New Tendencies: Art at the Threshold of the Information Revolution (1961–1978)* (Cambridge, MA: MIT Press, 2016).

6. Andrew Pickering, *The Cybernetic Brain: Sketches of Another Future* (Chicago: University of Chicago Press, 2009); Ronald R. Kline, *The Cybernetic Moment: Or Why We Call Our Age the Information Age* (Baltimore: Johns Hopkins University Press, 2015).

7. Background on Maxwell comes from several sources including his November 6, 1991 obituary in the *New York Times*, Richard Goldstein, "Robert Maxwell, World War II Hero Who Fell on a Grenade, Dies at 98," *New York Times*, May 13, 2019, https://nyti.ms/30kRwaW*;* and Brian Cox, "The Pergamon Phenomenon, 1951–1991: Robert Maxwell and Scientific Publishing," *Learned Publishing* 15, no. 4 (2002): 273–278, doi:10.1087/095315102760319233.

8. May 3, 1965 letter from Malina to Maxwell; Folder 1, Box 23, FM/LOC.

9. For example Bronowski's "The Creative Process," *Scientific American*, September 1958, 58–65.

10. Quotes from Oppenheimer's original proposal, prepared in 1967 and accompanying history of the venture; Box 5, E/UCB, as well as Frank Oppenheimer, "The Palace of Arts and Science: An Exploratorium at San Francisco, California, U.S.A.," *Leonardo* 5, no. 4 (1972): 343–346, https://www.muse.jhu.edu/article/597074.

11. Stephen Petersen, "Innovation and the Rhetoric of Plagiarism: The Klein/Takis Rivalry," *Visual Resources* 16, no. 2 (2000): 155–168, doi:10.1080/01973762.2000.9658546.

12. April 2, 1974 letter from Malina to Richard Land and November 23, 1972 letter from Malina to Richard K. Hillis; Folder 18, Box 37 and Folder 8, Box 26, FM/LOC.

13. Billy Klüver, "Theatre and Engineering: An Experiment—2. Notes by an Engineer," *Artforum* 5, no. 6 (1967): 31.

14. Published as Frank J. Malina, "Some Reflections on the Differences between Science and Art," draft essay from late 1964; later published in *DATA: Directions in Art, Theory, and Aesthetics*, ed. Anthony Hill (Greenwich, CT: New York Graphic Society, 1969), 134–149.

15. Ibid., 136.

16. For example, Ellen Winner, *How Art Works: A Psychological Exploration* (New York: Oxford University Press, 2018); also Tom Mashberg, "Did You Like that Sketch? Science Wants to Know Why," *New York Times*, July 10, 2018, https://nyti.ms/2KV8Xa9 (appeared online July 8, 2018 as "Do You Like 'Dogs Playing Poker'? Science Would Like to Know Why"). For quantification, Samuel P. Fraiberger, et al., "Quantifying Reputation and Success in Art," *Science* 362, no. 6416 (2018): 825–829.

17. Malina, "Some Reflections on the Differences between Science and Art," 139–140.

18. Brian O'Doherty, "'The Method': Overdocumentation of Modern Art by Misapplied Scholarship," *New York Times*, November 24, 1963, https://nyti.ms/1RBgkR7; Tom Wolfe, *The Painted Word* (New York: Farrar, Strauss, and Giroux, 1975).

19. Quotes from July 20, 1965 memorandum from Malina to Pergamon Press Art Journal Study Group; Folder 1, Box 23 and August 12, 1967 letter from Malina to Alcopley (Alfred L. Copley); Folder 3, Box 23; FM/LOC.

20. Figures from November 1968 memo to Pergamon Press; Folder 13, Box 23, FM/LOC.

21. March 13, 1968 letter; Folder 6, Box 23, FM/LOC.

22. February 2, 1968 letter from Malina to Leon Golub, April 22, 1968 letter from Malina to Alcopley (Alfred L. Copley), September 20, 1968 note; Folders 6 and 7, Box 23, FM/LOC. Wolfe, *The Painted Word*.

23. October 19, 1971 letter from Malina to David Rosenboom; Folder 13, Box 25, FM/LOC.

24. December 21, 1968 letter from Malina to William R. Sears; Folder 14, Box 23, FM/LOC.

25. October 25, 1971 letter from Malina to J. J. Gibson; Folder 19, Box 35, FM/LOC.

26. April 4, 1967 letter from Malina to Anthony Hill and May 16, 1969 letter from Malina to Frederick Hammersley; Folder 2, Box 23 and Folder 5, Box 24, FM/LOC.

27. May 28, 1969 letter from Malina to Peter Lloyd Jones; Folder 5, Box 24, FM/LOC.

28. December 29, 1971 letter from Malina to Alcopley (Alfred L. Copley); Folder 7, Box 34, FM/LOC.

29. February 21, 1969 letter from Malina to Klüver (emphasis in original); Folder 2, Box 24, FM/LOC.

30. March 1, 1973 letter from Malina to Jacques Mandelbrojt; Folder 12, Box 26, FM/LOC.

31. May 28, 1969 letter from Malina to Peter Lloyd Jones; Folder 5, Box 24, FM/LOC.

32. David Bohm, "On Creativity," *Leonardo* 1, no. 2 (1968): 137–149, https://www.muse.jhu.edu/article/596552; Myron A. Coler, "Creativity in Technology and the Arts," *Leonardo* 1, no. 3 (1968): 265–272, https://www.muse.jhu.edu/article/596574.

33. For example, Hans Wilhelmsson, "Holography: A New Scientific Technique of Possible Use to Artists," *Leonardo* 1, no. 2 (1968): 161–169, https://www.muse.jhu.edu/article/596556.

34. James J. Gibson, "The Information Available in Pictures," *Leonardo* 4, no. 1 (1971): 27–35, https://www.muse.jhu.edu/article/59687. Information about the debate is available online on *The Gombrich Archive* website, https://gombrich.co.uk/gombrichgibson-dispute/. As of May 2019, according to JSTOR, Gibson's essay had been cited close to 600 times. Gibson's personal and professional papers at Cornell (JJG/CU) contain a good record of his correspondence with Malina over the years which I consulted.

35. February 21, 1968 letter from Malina to G. F. Richards; Folder 13, Box 23, FM/LOC.

36. December 29, 1971 letter from Malina to Alcopley (Alfred L. Copley); Folder 7, Box 34, FM/LOC.

37. Eugene Garfield, "Arts and Humanities Journals Differ from Natural and Social Science Journals—But Their Similarities Are Surprising," *Current Comments* 47 (November 22, 1982): 5–11, http://www.garfield.library.upenn.edu/essays/v5p761y1981-82.pdf.

38. Frank J. Malina, "Leonardo: The First Decade," *Leonardo*, 11, no. 1 (1978): 1–2, https://www.muse.jhu.edu/article/598831; Roger Malina, in discussion with the author, December 7, 2015; copy in the author's collection.

39. Malina, "Leonardo."

40. Douglas M. Davis, "Gyorgy Kepes: Searcher in the New Landscape," *Art in America* 56, no. 1 (1968): 38–40. There is a robust amount of scholarship on Kepes's career. I'm drawing, among others, on two superb sources: Anne Collins Goodyear, "The Relationship of Art to Science and Technology in the United States, 1957–1971: Five Case Studies" (PhD diss., University of Texas at Austin, 2002), ProQuest (305503573), which has an entire chapter devoted to Kepes, as well as John R. Blakinger's excellent book *Gyorgy Kepes: Undreaming the Bauhaus* (Cambridge, MA: MIT Press, 2019).

41. Goodyear, "The Relationship of Art to Science and Technology in the United States, 1957–1971," 162, reflects on this.

42. Gyorgy Kepes, "The Visual Arts and Sciences: A Proposal for Collaboration," *Daedalus* 94, no. 1 (1965): 117–134.

43. March 19 and June 9, 1976 letters from Malina to John Holloway; Folder 7, Box 37, FM/LOC.

44. Kepes, "The Visual Arts and Sciences," 122.

45. Leo L. Beranek, "Poles and Zeros: Should Scientists and Artists Be Rubbed Together?," *Proceedings of the IEEE* 53, no. 11 (1965): 1687, doi:10.1109/PROC.1965.4340.

46. November 22, 1966 letter from Cyril S. Smith to Kepes; CAVS/MIT.

47. June 17 and July 7, 1965 letters between Kepes to Stratton; this and other correspondence are in Folder "Center for Advanced Visual Studies," Box 29, AC 134, SC/MIT. Also, "Proposal for The Center for Advanced Visual Studies," December 1965, CAVS/MIT.

48. "Introduction to Humanities Section of Ford Proposal," undated, but likely 1967; "Committee on the Visual Arts," Box 6, AC 48, SC/MIT.

49. Gyorgy Kepes, "A Collaborative Approach at the Center for Advanced Visual Studies," April 1966; Box 193, AC 8, SC/MIT.

50. July 13 ,1967 Press Release; CAVS/MIT.

51. Jane H. Kay, "Art and Science on the Charles," *Art in America* 55, no. 5 (1967): 62–67.

52. Grace Marmor Spruch was a faculty member for forty-seven years at Rutgers University. Her obituary in the May 14, 2019 *New York Times*, noted her longstanding love of art and music.

53. Lyndon B. Johnson, "Remarks at the Signing of the Arts and Humanities Bill" (speech, September 29, 1965), https://www.presidency.ucsb.edu/documents/remarks-the-signing-the-arts-and-humanities-bill.

54. Grace Marmor Spruch, "Two Contributions to the Art and Science Muddle: 2. A Report on a Symposium on Art and Science Held at the Massachusetts Institute of Technology, March 20–22, 1968," *Artforum* 7, no. 5 (1969): 28–32; a draft of Kepes's speech is in Box 20, AC 431, SC/MIT.

55. Quotes from Spruch, "Two Contributions to the Art and Science Muddle."

56. Ibid.

57. Biographical material on Burnham's career comes from the file of correspondence and other materials CAVS maintained (CAVS/MIT) as well as an anthology of his writings edited by Melissa Ragain, *Dissolve into Comprehension: Writings and Interviews, 1964–2004* (Cambridge, MA: MIT Press, 2015).

58. "Biographical Data for Jack. W. Burnham," ca. 1968; CAVS/MIT; Jack Burnham, "System Esthetics," *Artforum* 7, no. 1 (1968): 30–35.

59. Jack Burnham, *Beyond Modern Sculpture: The Effects of Science and Technology on the Sculpture of this Century* (New York: George Braziller, 1968); the quote comes from Burnham's proposal for the book, ca. 1967; CAVS/MIT.

60. All of these references appear on the first page alone of Burnham's "System Esthetics."

61. This sequence of events is covered by a number of historians, including Dorothy Nelkin, *The University and Military Research: Moral Politics at MIT* (Ithaca: Cornell University Press, 1972).

62. Burnham, "System Esthetics," 31, emphasis in original.

63. Jack Burnham, "Some Thoughts on Systems Methodology Applied to Art," undated, but likely late 1967; CAVS/MIT.

64. An analysis of Burnham's thinking is Caroline A. Jones's essay "System Symptoms," *Artforum* 51, no. 1 (2012): 113–116; see also, Edward A. Shanken, ed., *Documents of Contemporary Art: Systems* (Cambridge, MA: MIT Press, 2015).

65. October 18, 1968 letter from Hill to Malina; Folder 5, Box 36, FM/LOC.

66. Bannard's letter appears on page 4 of the November 1968 issue of *Artforum*.

67. Louis Vaczek, book review in *Technology and Culture* 11, no. 4 (1970): 655–659.

68. Emphasis in original; the photograph and the quote appear in Burnham's essay, "The Aesthetics of Intelligent Systems" in *On the Future of Art*, ed. Edward F. Fry (New York: Viking, 1970): 95–122, which was based on a 1969 lecture he gave at the Guggenheim Museum.

69. Jack Burnham, "Real Time Systems," *Artforum* 8, no. 1 (1969): 49–55.

70. John Chandler, "Art in the Electric Age," *Art International* 13, no. 2 (1969): 19–25.

71. Burnham, "Real Time Systems," 55.

72. Douglas M. Davis, "Conversations with Gyorgy Kepes, Billy Klüver, and James Seawright," *Art in America* 56, no. 1 (1968): 39. A slightly different version also appeared in Douglas M. Davis, *Art and the Future: A History/Prophecy of the Collaboration between Science, Technology, and Art* (New York: Praeger, 1973), 115–119.

73. Jack Burnham, "The Panacea that Failed," in *Myths of Information: Technology and Post-Industrial Culture*, ed. Kathleen Woodward (Madison, WI: Coda Press, 1980), 200–215; emphasis in original.

74. Burnham's answers to a CAVS questionnaire, ca. 1992; CAVS/MIT.

75. Richard Brautigan, "All Watched Over by Machines of Loving Grace," in *Trout Fishing in America, The Pill versus the Springhill Mine Disaster, and In Watermelon Sugar: Three Books in the Manner of Their Original Editions* (Boston, MA: Houghton Mifflin/Seymour Lawrence, 1989), 2:1. Brautigan's 1967 poem "At the California Institute of Technology," which he wrote while a poet-in-residence at Caltech, also appears in his 1968 collection *The Pill versus the Springhill Mine Disaster*.

76. Easily seen via Google Ngram search for "cybernetics," a crude but indicative metric.

77. For information on the press, see Walter van der Star, Jasia Reichardt, and Nick Wadley, *Biography of a Publishing House: Stefan and Franciszka Themerson & Gabberbocchus* (Amsterdam: Huis Clos, 2017), while biographical information on Reichardt is from María Fernández, "Detached from HiStory: Jasia Reichardt and *Cybernetic Serendipity*," *Art Journal* 67, no. 3 (2008): 6–23, doi:10.1080/00043249.2008.10791311.

78. Jasia Reichardt, "Gaberbocchus Press and the Common Room," *Interdisciplinary Science Reviews* 42, no. 1–2 (2017): 30–41, doi:10.1080/03080188.2017.1297161.

79. Brent MacGregor, "*Cybernetic Serendipity* Revisited," in *White Heat, Cold Logic: British Computer Art, 1960–1980*, ed. Paul Brown, Charlie Gere, Nicholas Lambert, and Catherine Mason (Cambridge, MA: MIT Press, 2008), 83–93, as well as the catalog associated with the show. This was first published in July 1968, just before the exhibit opened, as special issue of *Studio International* and then later as a book by Praeger, both with the title *Cybernetic Serendipity: The Computer and the Arts*.

80. Jasia Reichardt, ed., *Cybernetic Serendipity: The Computer and the Arts* (New York: Praeger, 1968), 5.

81. Jasia Reichardt, "Cybernetics, Art, and Ideas," in *Cybernetics, Art, and Ideas*, ed. Jasia Reichardt (Greenwich, CT: New York Graphic Society, 1971), 11–17; Jasia Reichardt, "'Cybernetic Serendipity': Getting Rid of Preconceptions," *Studio International* 176, no. 905 (November 1968): 176–178.

82. A good introduction to Tsia's work is *The Cybernetic Sculpture Environment of Tsai Wen-Ying* (New York: Center Art and Science Foundation, 1997), printed in both Chinese and English.

83. "Tsai's Cybernetic Sculptures," July 1968 information from Howard Wise Gallery; CAVS/MIT; John Canaday, "Art: Less Quiet Stones," *New York Times*, May 18, 1968, https://nyti.ms/1kPtqzx; Jonathan Benthall, "The Cybernetic Sculpture of Tsai Wen-Ying," *Studio International* 177, no. 909 (March 1969): 126–129.

84. Jane Livingston, "Kansas City," *Artforum* 7, no. 1 (1968): 66–67.

85. March 3 or 4, 1934 press release from MoMA, https://www.moma.org/documents/moma_press-release_325017.pdf.

86. K. G. Pontus Hultén, *The Machine as Seen at the End of the Mechanical Age* (New York: Museum of Modern Art, 1968), 3. Also, comments in Henry J. Seldis, "New Age of Technology in N.Y. Museum Show," *Los Angeles Times*, December 1, 1968.

87. The competition was announced in several places, including the November 12, 1967 issue of the *New York Times* and the January 1968 issue of *Scientific American*; a reprint of this appeared in Hultén, *The Machine as Seen at the End of the Mechanical Age*, 198.

88. Noted in *E.A.T. Proceedings*, no. 9 (May 1969): 13.

89. Descriptions from Alexander Keneas, "Museum Unites Art and Science," *New York Times*, November 12, 1968, https://nyti.ms/1PFAgTH. There was some confusion over Turner and Tsai's contributions given that they both were engineers and the latter had made several pieces, all titled *Cybernetic Sculpture*. E.A.T. and MoMA clarified their roles, noting that the two men had split the money; November 27, 1968 press release, https://www.moma.org/documents/moma_press-release_326596.pdf.

90. "Some More Beginnings," *Techne* 1 no. 1 (April 14, 1969): 1–2; EAT/AAA.

91. Grace Glueck, "Art Comes Clanking from All over into Two Museums," *New York Times*, November 28, 1968, https://nyti.ms/1PFzxll; Seldis, "New Age of Technology in N.Y. Museum Show."

92. January 11, 1960 MoMA press release, https://www.moma.org/momaorg/shared/pdfs/docs/press_archives/2603/releases/MOMA_1960_0002_2.pdf.

93. Billy Klüver, "The Artist and Industry" (lecture, December 16, 1968, Museum of Modern Art, New York); EAT/AAA.

CHAPTER 7

1. Barbara Rose, "Vogue's Spotlight: Art," *Vogue*, September 1, 1970, 304.

2. Theodore Roszak, *The Making of a Counter Culture: Reflections on a Technocratic Society and Its Youthful Opposition* (Garden City, NY: Anchor/Doubleday, 1969), 215.

3. Information about Nowlin comes from several personal conversations with the author as well as a personal retrospective: "@Caltech: Art, Science, and Technology, 1969–1971," *Leonardo* 50, no. 5 (2017): 443–447, https://www.muse.jhu.edu/article/670950. Information on the Caltech program is in Lukas Van Vuuren, "Two Year Report on the Development of the Workshop and Gallery," April 19, 1971; Folder 18, Box 4, BAG/AAA.

4. Christy Fox, "Art Amenities at Caltech Think Tank," *Los Angeles Times*, April 19, 1970.

5. For surveys of the Los Angeles art scene, see Peter Plagens's classic *Sunshine Muse: Contemporary Art on the West Coast* (New York: Praeger, 1974) along with more recent books, including the wonderful edited collection by Rebecca Peabody, et al., *Pacific Standard Time: Los Angeles Art, 1945–1980* (Los Angeles: Getty Research Institute, 2011); Hunter Drohojowska-Philp, *Rebels in Paradise: The Los Angeles Art Scene and the 1960s* (New York: Henry Holt, 2011); and William Hackman's *Out of Sight: The Los Angeles Art Scene of the Sixties* (New York: Other Press, 2015).

6. Hackman, *Out of Sight*, 6–7.

7. Max Kozloff, "West Coast Art: The Vital Pathology," *Nation*, August 24, 1964, 76.

8. Roy Duncan, "Pasadena, the Old Order Changeth," *Los Angeles* (December 1963): 39.

9. "Temple on the Tar Pits," *Time*, April 2, 1965, 74; and "Brightness in the Air," *Time*, December 18, 1964, 62–72.

10. Charles Champlin, "Los Angeles in a New Image," *Life*, June 20, 1960, 89; and Mitchell Wilder, "A Stirring in the Pacific Paint Pot," *Saturday Review*, October 20, 1962, 56.

11. Joseph Masheck, "New York: Masterpieces of Fifty Centuries, Metropolitan Museum of Art; Brice Marden, Bykert Gallery; California Color, Pace Gallery; Robert Smithson, Dwan Gallery," *Artforum* 9, no. 5 (1971): 72–73.

12. Barbara Rose, "Los Angeles: The Second City," *Art in America* 54, no. 1 (1966): 110–115.

13. Quotes from Edward Kienholz, "Maurice Tuchman: Bronx Cowboy & Super Curator," *Los Angeles Times*, June 4, 1967. Additional biographical material from William Wilson, "Maurice Tuchman: Still the Enfant Terrible," *Los Angeles Times*, October 22, 1989; and Maurice Tuchman, in discussion with the author, August 20, 2013.

14. Maurice Tuchman, ed., *Art and Technology: A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971* (Los Angeles: Los Angeles County Museum of Art, 1971), https://archive.org/details/reportonarttechn00losa.

15. Kienholz, "Maurice Tuchman."

16. In 1967, for example, more than 300,000 people worked in Orange and Los Angeles counties for the aerospace industry. These numbers increased dramatically if one included the regional electronics industry. Allen J. Scott, *Technopolis: High-Technology Industry and Regional Development in Southern California* (Berkeley: University of California Press, 1994); also, Layne Karafantis and Stuart W. Leslie, "'Suburban Warriors': The Blue-Collar and Blue Sky Communities of Southern California's Aerospace Industry," *Journal of Planning History* 18, no. 1 (2019): 3–26, doi:10.1177/1538513217748654.

17. Rachel Rivenc, *Made in Los Angeles: Materials, Processes, and the Birth of West Coast Minimalism* (Los Angeles: Getty Conservation Institute, 2016).

18. Masheck, "New York."

19. Information on Brogan is from Margaret M. Honda, "Found Technology: The Art Fabrication Business of Jack Brogan" (master's thesis, University of Delaware, 1991), ProQuest (303944951); while more technical information is in Rivenc, *Made in Los Angeles*.

20. Evelyn C. Hankins, ed., *Robert Irwin: All the Rules Will Change* (New York: DelMonico Books, 2016).

21. Tuchman, *Art and Technology*, 9.

22. Grace Glueck, "Los Angeles Museum Playing Matchmaker," *New York Times*, December 13, 1968, https://nyti.ms/1PFws51.

23. The Long Beach show is discussed in chapter 1 of Christopher R. De Fay, "Art, Enterprise, and Collaboration: Richard Serra, Robert Irwin, James Turrell, and Claes Oldenburg at the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971" (PhD diss., University of Michigan, 2005), ProQuest (305458789).

24. A fascinating topic in its own right, useful information on the APG is found via John A. Walker, "APG: The Individual and the Organisation," *Studio International* 191, no. 980 (March/April 1976): 162–164; Peter Eleey, "The Context is Half the Work," *Frieze*, no. 111, November 2007; and, more recently, Steven Duval, "Identity, Rhetoric, and Method in the Collaborations of Experiments in Art and Technology, The Artist Placement Group, and the Art and Technology Program at the Los Angeles County Museum of Art," in *Hybrid Practices: Art in Collaboration with Science and Technology in the Long 1960s,* ed. David Cateforis, Steven Duval, and Shepherd Steiner (Berkeley: University of California Press, 2018), 45–60.

25. June 5, 1967 letter from Marilyn Chandler to Maurice Tuchman; Box 1, Folder 10, AT/LACMA.

26. Ibid.

27. Tuchman, *Art and Technology*, 10.

28. Maurice Tuchman, in discussion with the author, August 20, 2013.

29. Richard P. Feynman, *Surely You're Joking Mr. Feynman: Adventures of a Curious Character* (New York: Norton, 1985), 276–278.

30. Years later, Channa Davis Horwitz recalled that Tuchman included her proposal in the final report/catalog but "did not feel it was appropriate for a woman to discuss an engineering project with the male industrial scientists involved with the show"; Folder 3, Box 3, AT/LACMA.

31. Maurice Tuchman, "Confidential Memorandum" (1967), which also doubled as a party invitation in which guests were asked to bring an object representing the past while coming "dressed as you hope to dress in 1984"; AT/LACMA.

32. In 1980, Jack Burnham said he suspected the total outlay for Tuchman's project was equivalent to $500,000 to $1 million; "Art and Technology: The Panacea that Failed," in *Myths of Information: Technology and Postindustrial Culture*, ed. Kathleen Woodward (Madison, WI: Coda, 1980), 208.

33. Tuchman, *Art and Technology*, 17; he made a similar comparison in a 1971 radio interview with Clare Loeb (later Clare Spark) that was broadcast on 90.7 KPFK, a Los Angeles public radio station. In the spring of 1971, Loeb did a dozen radio interviews with artists and engineers: Robert Whitman; Claes Oldenburg; John Forkner; Jane Livingston; Ed Wortz; James Lee Byars; Billy Klüver; Robert Irwin; Boyd Mefferd; Newton Harrison; Maurice Tuchman; and Rockne Krebs, individual interviews with Clare Loeb, *Art and Technology*, Pacifica Radio Archives, radio audio, broadcast between February 7–July 19, 1971, https://www.pacificaradioarchives.org/recording/bb445801-13, transcripts in the author's possession.

34. Sample artist and sponsor contracts are included in Tuchman, *Art and Technology*, and pages 12–18 discusses the contracts.

35. Guy Williams, letter in February 1969 issue of *Artforum*, 4, 6.

36. Tuchman, *Art and Technology*, 16, emphasis mine.

37. Grace Glueck, "Los Angeles Museum Playing Matchmaker"; also William Wilson, "Corporations Join Creative Art Experiment," *Los Angeles Times*, October 22, 1968, ProQuest Historical Newspapers (156120786).

38. Henry J. Seldis, "Artists, Firms Join in Museum Project in L.A.," *Los Angeles Times*, December 12, 1968, and "Art, Technology: Aesthetic Entente in the Making" *Los Angeles Times*, December 29, 1968.

39. Roderick Nordell, "'We're Not Interested in Art,' the Man Said," *Christian Science Monitor*, May 13, 1968; Glueck, "Los Angeles Museum Playing Matchmake."

40. Tuchman, *Art and Technology*, 9. Related to this are larger changes in the nature of corporate patronage; see Mark W. Rectanus, *Culture Incorporated: Museums, Artists, and Corporate Sponsorship* (Minneapolis: University of Minnesota Press, 2002).

41. "Artists Use an Industrial Palette," *Business Week*, November 8, 1969, 96–98.

42. De Fay, "Art, Enterprise, and Collaboration," 44–60.

43. Tuchman, *Art and Technology*, 11–17, notes that "this nomenclature was never comfortably accepted by us" but that he and his colleagues could come up with nothing better as a moniker.

44. Jane Livingston, "Thoughts on Art and Technology," in Tuchman, *Art and Technology*, 43–47.

45. Maurice Tuchman, in discussion with the author, August 20, 2013.

46. For example, Robert H. Haddow, *Pavilions of Plenty: Exhibiting American Culture Abroad in the 1950s* (Washington, DC: Smithsonian Institution Press, 1997); Jack Masey and Conway Lloyd Morgan, *Cold War Confrontations: US Exhibitions and Their Role in the Cultural Cold War* (Baden: Lars Müller, 2008).

47. William Grimes, "Jack Masey, Whose Exhibitions Showed American Culture to World, Dies at 91," *New York Times*, March 21, 2016, https://nyti.ms/22AMIt8; and Jack Masey, in discussion with author, August 26, 2013.

48. Masey's work is described in Masey and Morgan, *Cold War Confrontations*. On the vogue for inflatable structures, see Marc Dessauce, ed., *The Inflatable Moment: Pneumatics and Protest in '68* (New York: Princeton Architectural Press, 1999).

49. April 17, 1968 letter from Jack Masey to USIA; JM/NYC; July 21, 1967 "Typical Invitation Letter" from USIA director to architect Paul Rudolph; Box 7, AC 48, SC/MIT.

50. A point suggested by De Fay, “Art, Enterprise, and Collaboration,” 37.

51. William Wilson, “L.A. ‘Art, Technology’ Prepares for Japan Expo,” *Los Angeles Times*, August 28, 1969.

52. Kienholz, “Maurice Tuchman.”

53. Biographical information on Garmire comes from a number of sources, including personal correspondence with the author and an essay in Emma Ideal and Rhiannon Meharchand, eds., *Blazing the Trail: Essays by Leading Women in Science* (Lexington, KY: CreateSpace Independent Publishing Platform, 2013). Garmire’s positive experiences as a physics student contrast with Evelyn Fox Keller’s depiction in “The Anomaly of a Woman in Physics,” in *Working It Out: 23 Women Writers, Artists, Scientists, and Scholars Talk About Their Lives and Work*, ed. Sara Ruddick and Pamela Daniels (New York: Pantheon, 1977), 77–87.

54. For women at Caltech, see chapter 5 of Amy Sue Bix, *Girls Coming to Tech! A History of American Engineering Education for Women* (Cambridge, MA: MIT Press, 2014), from which the quotes are drawn.

55. Elsa M. Garmire, interview by Joan Bromberg, February 4, 1985, https://www.aip.org/history-programs/niels-bohr-library/oral-histories/4621; as well as personal correspondence with the author.

56. Holly Meyers, “A 50’s Housewife as Performance Art,” *Los Angeles Times*, September 18, 2011. Garmire’s recollections are from a 1970 interview with Nilo Lindgren; Folder 6, Box 140, EAT/GRI. On Smith see, Kathy Noble, “How a Dissatisfied Housewife Was Saved by Radical Performance (and a Xerox Machine),” *Artsy*, March 5, 2018, https://www.artsy.net/article/artsy-editorial-dissatisfied-housewife-saved-radical-performance-xerox-machine.

57. Elsa Garmire, personal correspondence with the author.

58. July 2, 1968 letter from Garmire to Francis Mason; Folder 14, Box 124, EAT/GRI.

59. Bochner’s residency is described in Grace Glueck, “$75,000 in Grants to Spur Art Test,” *New York Times*, September 19, 1968, https://nyti.ms/1Y8x0TI. Whitman’s work was discussed in the October 27 issue of *Time*, 64.

60. A transcript of the entire panel, which took place on December 29, 1968; Folder 14, Box 124, EAT/GRI.

61. Elsa Garmire, personal correspondence with the author.

62. Interest in having a Los Angeles chapter dates back at least to June 1967 as recorded in correspondence between David MacDermott and Klüver; Folder 12, Box 29, EAT/GRI. The activities of E.A.T./L.A. are documented in a collection (2003.M.12) at the GRI as well as materials in Box 29, EAT/GRI.

63. “Cybernetic Moon Landing Celebration,” undated press release, likely July 1969; Folder 13, Box 29, EAT/GRI.

64. Caroline Hinkley, personal correspondence with the author.

65. Steve Lerner, “The Age of Lunacy on a Muddy Meadow,” *Village Voice*, July 24, 1969.

66. William Wilson, “Lunar Walk Hailed at Art-Science Fete,” *Los Angeles Times*, July 22, 1969.

67. Elsa Garmire, interview by Nilo Lindgren, 1970; Folder 6, Box 140, EAT/GRI.

68. Elsa Garmire, “Art and Technology—Ruminations of an Engineer,” reprinted in *Survey* 1, (January 1970): 6.

69. Elsa Garmire, personal correspondence with the author, as well as images and presentations of her work she shared with me.

70. Henry J. Seldis and William Wilson, “Art Walk,” *Los Angeles Times*, February 5, 1971.

71. “Education Study Gets Gift,” *New York Times*, November 14, 1968, https://nyti.ms/1N1ehaZ. Pepsi’s statement, dated November 11, 1968, and based on a press conference at MoMA, also

noted its intent to "explore new and effective ways to appeal to young people around the world"; SNB/BM.

72. Chapter 5 of Anne Collins Goodyear, "The Relationship of Art to Science and Technology in the United States, 1957–1971: Five Case Studies" (PhD diss., University of Texas at Austin, 2002), ProQuest (305503573), rightly notes the advance preparation E.AT. had already done. This reluctance can be found in several of Klüver statements including a January 8, 1970 interview with Nilo Lindgren; Folder 8, Box 140, EAT/GRI.

73. "MemCon," undated but sometime mid-February 1968; Folder 24, Box 49, EAT/GRI.

74. Robert Breer, quoted in Calvin Tomkins's notes; II.B.11, CT/MoMA.

75. David Thomas, interview by Calvin Tomkins, January 28, 1970; II.B.11, CT/MoMA.

76. Marc Treib, *Space Calculated in Seconds: The Philips Pavilion, Le Corbusier, Edgard Varèse* (Princeton: Princeton University Press, 1996).

77. Breer's recollections come from a January 13, 1970 interview conducted by Calvin Tomkins; II.B.11; CT/MoMA. This and the other extensive research Tomkins did formed the basis of a lengthy essay, "Onward and Upward with the Arts: E.A.T," *New Yorker*, October 3, 1970, 83–133, later republished as "Outside Art" in the collection *Pavilion: Experiments in Art and Technology*, ed. Billy Klüver, Julie Martin, and Barbara Rose (New York: E. P. Dutton, 1972), 105–165. Additional material and quotes on Breer come from a December 4, 1969 interview with Nilo Lindgren; Folder 5, Box 140, EAT/GRI.

78. Meeting account drawn from Tomkins's notes, his article "Onward and Upward with the Arts: E.A.T.," as well as Nilo Lindgren's interviews (Box 140, EAT/GRI), which served as the basis for his essay "Into the Collaboration," which appeared in Klüver, Martin, and Rose, *Pavilion*, 3–59.

79. Lindgren, "Into the Collaboration," 9.

80. Tomkins, "Onward and Upward with the Arts: E.A.T," 98.

81. For a sense of this scene, see the May 27, 1966 issue of *Life* magazine and its cover article, "New Madness at the Discothèque," and accompanying groovy photos.

82. See chapter 2 of Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006); as well as Michael Oren, "USCO: 'Getting out of Your Mind to Use Your Head,'" *Art Journal* 69, no 4 (2010): 76–95.

83. "Notes from Meeting," September 23, 1968 in Folder 2, Box 48; "Agreement Letter," October 4, 1968 in Folder 1, Box 48; Klüver's January 8, 1970 interview with Nilo Lindgren; in Folder 8, Box 140; all EAT/GRI. In addition, Lindgren's "Into the Collaboration," 8.

84. David Bourdon, "$E = MC^2$ à Go-Go," *Art News* 64, no. 9 (1966): 22–25, 57–59.

85. I'd like to thank Beau R. Ott, a collector of Myers's work, for sharing this information with me. Also, see Linda Dalrymple Henderson, *Reimagining Space: The Park Place Gallery Group in 1960s New York* (Austin, TX: Blanton Museum of Art, 2008). Just as the art-and-technology movement has been largely absent in traditional histories, the Park Place Gallery, as Henderson notes, is typically excluded from standard narratives of the 1960s-era New York art scene.

86. Forrest Myers, interview by Nilo Lindgren, December 4, 1969; Folder 8, Box 140, EAT/GRI.

87. Robert Whitman, "Notes," October 2, 1968; Folder 35, Box 43, EAT/GRI.

88. Calvin Tomkins, "PepsiCo Notes," undated; II.B.11; CT/MoMA

89. Robert Breer, interview by Calvin Tomkins, January 13, 1970; II.B.11; CT/MoMA.

90. John Pearce, interview by Nilo Lindgren, January 29, 1970; Folder 6, Box 140, EAT/GRI.

91. Rauschenberg's pivotal role at this point is reported in almost all of the interviews and recollections of this period collected by Nilo Lindgren and Calvin Tomkins.

92. Tomkins's notes on Pearce; II.B.11; CT/MoMA.

93. Midori Yoshimoto, "From Space to Environment: The Origins of *Kankyō* and the Emergence of Intermedia Art in Japan," *Art Journal* 67, no. 3 (2008): 24–45.

94. Forrest Myers, interview by Nilo Lindgren, December 4, 1969; Folder 8, Box 140, EAT/GRI.

95. April 1969 telegram from John Pearce in Osaka to E.A.T.; Folder 19, Box 43, EAT/GRI.

96. A technical description of the work appears in Eric Rawson, "Pond," *Techne* 1, no. 1 (1969): 10.

97. John Gruen, "Art in New York: Spectator Participation," *New York Magazine*, November 11, 1968, 19.

98. Milton Brown, Sam Hunter, John Jacobus, Naomi Rosenblum, and David Sokol, *American Art: Painting, Sculpture, Architecture, Decorative Arts, Photography* (New York: Abrams, 1979), 587.

99. Reconstruction based on Tomkins's notes from January 28, 1970 Thomas interview; II.B.11; CT/MoMA.

100. This account of E.A.T.'s presentation is drawn from Tomkins's notes, his article "Onward and Upward with the Arts" in the *New Yorker*, Lindgren's interviews, and his essay "Into the Collaboration."

101. "Preliminary Cost Estimate," December 3, 1968; Folder 11, Box 43, EAT/GRI.

102. December 9, 1968 letter from Pottasch to Thomas; Folder 1, Box 43; June 24, 1969 letter from Pepsi to E.A.T; Folder 8, along with other materials, Box 171, all EAT/GRI.

103. As described in Tomkins's notes; II.B.11; CT/MoMA. Also, December 9, 1969 letter from Pottasch to Thomas; Folder, 1, Box 43, EAT/GRI

104. Tomkins's notes on January 8, 1970 Klüver interview; II.B.11; CT/MoMA.

105. Tomkins's notes on February 5, 1970 Pottasch interview; II.B.11; CT/MoMA.

106. February 25, 1969 letter from Klüver and Rauschenberg to Shelton Stone; Folder 35, Box 43, EAT/GRI.

107. Klüver, September 30, 1969 statement, in press materials for Pepsi Pavilion; EAT/AAA.

CHAPTER 8

1. December 24, 1972 letter from Waldhauer to his mother; FW.

2. Alvin Weinberg's *Reflections on Big Science* (Cambridge, MA: MIT Press, 1967), was based on earlier articles he had written, including "Impact of Large-Scale Science on the United States," *Science* 134, no. 3473 (1961): 161–164.

3. James H. Capshew and Karen A. Rader, "Big Science: Price to the Present," *Osiris* 7 (1992): 2–25.

4. Weinberg, "Impact of Large-Scale Science on the United States," 161–162.

5. See, for example, essays in Steven Shapin, *Never Pure: Historical Studies of Science as if It was Produced by People with Bodies, Situated in Time, Space, Culture, and Society, and Struggling for Credibility and Authority* (Baltimore: Johns Hopkins University Press, 2010).

6. "Artists Use an Industrial Palette," *Business Week*, November 8, 1969, 96–98.

7. Andrew Hudson, "Krebs is Starkly Courageous," *Washington Post*, January 29, 1967.

8. Quotes are from a 1971 interview Krebs did with Clare Loeb (later Clare Spark) for Pacifica Radio: Rockne Krebs, interview by Clare Loeb, *Art and Technology*, Pacifica Radio Archives, radio audio, broadcast between February 7–July 19, 1971, PRA archive no. BB4458.01-.13, https://www.pacificaradioarchives.org/recording/bb445801-13, transcripts in the author's possession; and a 1968 press release from the Washington Gallery of Modern Art, graciously shared by Heather Krebs.

9. Handwritten notes by Krebs, summer 1969; "Rockne Krebs" folder, Box 3, AT/LACMA

10. Jane Livingston, “Rockne Krebs,” in *Art and Technology: A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971,* ed. Maurice Tuchman (Los Angeles: Los Angeles County Museum of Art, 1971), 166, https://archive.org/details/reportonarttechn00losa.

11. Laurence Hubby, in discussion with the author, June 14, 2018.

12. Jane Livingston, “Rockne Krebs,” 168; Rockne Krebs, Light Reflection Apparatus, US Patent 3,622,228, filed September 24, 1969, and issued November 23, 1971, https://patents.google.com/patent/US3622228A/en?oq=3%2c622%2c228.

13. Jane Livingston, “Rockne Krebs,” 174, emphasis in original.

14. Henry J. Seldis, “The Art of Tomorrow,” *Los Angeles Times*, June 7, 1970; and Paul Richard, “Rockne Krebs and his Electric, Fog-Filled Happening,” *Washington Post*, April 12, 1970.

15. Jane Livingston, “Rockne Krebs,” 174.

16. Laurence Hubby, in discussion with the author, June 14, 2018.

17. Rockne Krebs, interview by Clare Loeb, *Art and Technology*, Pacifica Radio Archives, radio audio, broadcast between February 7–July 19, 1971, PRA archive no. BB4458.01-.13, https://www.pacificaradioarchives.org/recording/bb445801-13, transcripts in the author’s possession.

18. For example, June 28, 1973 letter from Gyorgy Kepes to Krebs; RK.

19. Lucy Lippard and John Chandler, “The Dematerialization of Art,” *Art International* 12, no. 2 (1968): 31–36.

20. Composite quote from 1971 Clare Loeb interview with Whitman and Forkner and Whitman from Gail R. Scott, “Robert Whitman,” in *Art and Technology: A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971,* ed. Maurice Tuchman (Los Angeles: Los Angeles County Museum of Art, 1971), 340, https://archive.org/details/reportonarttechn00losa.

21. John F. Forkner, Light Display Instrument, US Patent 3,580,126, filed October 29, 1968, issued May 25, 1971, https://patents.google.com/patent/US3580126A/en?oq=%223%2c580%2c126%22.

22. Robert Whitman, in discussion with the author, December 31, 2014.

23. Scott, “Robert Whitman,” 340.

24. From Forkner’s notes, undated, excerpts of which were published in Tuchman’s *Art and Technology;* Folder 8, Box 6, AT/LACMA.

25. “Art and Technology Project,” May 27, 1969 memo from Forkner to R. Ball; Folder 8, Box 6, AT/LACMA.

26. “J. Forkner, Rough Draft,” undated but likely mid-1970; Folder 8, Box 6, AT/LACMA.

27. Ibid.

28. John F. Forkner, “The Construction of Robert Whitman’s Mirrors in Laguna Beach, California,” in Tuchman, *Art and Technology*, 352–358; also, Lael Morgan, “Art Environment Mirrors Team Effort,” *Los Angeles Times*, February 2, 1970.

29. Forkner, “The Construction of Robert Whitman’s Mirrors,” 358; and Robert Whitman and John F. Forkner, interview by Clare Loeb, *Art and Technology*, Pacifica Radio Archives, radio audio, broadcast between February 7–July 19, 1971, PRA archive no. BB4458.01-.13, https://www.pacificaradioarchives.org/recording/bb445801-13, transcripts in the author’s possession..

30. Scott, “Robert Whitman,” 349.

31. Ibid., 350.

32. Calvin Tomkins, “E.A.T. People Notes,” March 1970; II.B.11, CT/MoMA.

33. John F. Forkner, interviewed by Barbara Rose, March 10, 1970; Cassette 42, Box 10, BR/GRI.

34. Seldis, “The Art of Tomorrow.”

35. For example, a twenty-five-page State Department telegram on June 12, 1970 sent from Osaka to Washington, DC, summarizing international media coverage; JM/NYC.

36. Seldis, “The Art of Tomorrow.”

37. Jack Masey, in discussion with the author, January 6, 2014.

38. "United States Pavilion, Japan World Exposition, Osaka, 1970: A Report," November 1, 1970 USIA report; JM/NYC.

39. David L. Judd and Ronald MacKenzie, "The Cyclotron as Seen by . . . ," *Physics Today* 20, no. 8 (1967): 71–73, doi:10.1063/1.4725732.

40. "How Pepsi Pours It on in Japan," *Business Abroad*, October 2, 1967.

41. Alan M. Pottasch, interview by Calvin Tomkins, February 5, 1970; II.B.11, CT/MoMA.

42. Billy Klüver, "The Pavilion," in *Pavilion: Experiments in Art and Technology*, ed. Billy Klüver, Julie Martin, and Barbara Rose (New York: E. P. Dutton, 1972), ix–x; also, engineer John Pan in *Pavilion*, page 270, on "hardware" and "programming."

43. Alan Pottasch, interview by Calvin Tomkins, February 5, 1970, emphasis in original; II.B.11, CT/MoMA.

44. Klüver, Martin, and Rose, *Pavilion*, 237.

45. This is dated November 1968 and reproduced in Klüver, Martin, and Rose, *Pavilion*, 34.

46. James A. Bender, "Obituary: Ukichiro Nakaya," *Arctic* 15, no. 3 (1962): 242–243.

47. Biographical information comes from Anne-Marie Duguet, ed., *Fujiko Nakaya—Fog* (Paris: Éditions Anarchive, 2012); and Leigh Markopoulos and Marina McDougall, eds., *Over the Water: Fujiko Nakaya* (San Francisco: Exploratorium, 2013); January 16 and February 20, 1969 letters from Klüver to Nakaya; Folder 29, Box 43, EAT/GRI.

48. Fujiko Nakaya's experiments are recounted in her essay "Making of 'Fog' or Low Hanging Stratus Clouds," in Klüver, Martin, and Rose, *Pavilion*, 207–223.

49. Nakaya, "Making of 'Fog' or Low Hanging Stratus Clouds," 209.

50. Undated telegram, likely May 1969 from Klüver to Nakaya; Folder 7, Box 46, EAT/GRI.

51. Biographical material on Thomas Mee comes from an unpublished history of his company, kindly shared with me by his children, as well as conversations I had with them in 2012; see also, Mee Industries, http://www.meefog.com/.

52. Thomas Mee, interview by Nilo Lindgren, December 10, 1969; Folder 5, Box 140, E.A.T./Getty.

53. Nakaya's experimental approach is well documented in her essay "Making of 'Fog' or Low Hanging Stratus Clouds." Also, see Nilo Lindgren's essay "Into the Collaboration," in Klüver, Martin, and Rose, *Pavilion*, 40–48.

54. September 13, 1969 letter and proposal from Mee to E.A.T.; Folder 7, Box 46, EAT/GRI.

55. Lindgren, "Into the Collaboration," 48; Tomkins, "Outside Art," in Klüver, Martin, and Rose, *Pavilion,* 124.

56. Lindgren, "Into the Collaboration," 24.

57. Simon Sadler, *Archigram: Architecture without Architecture* (Cambridge, MA: MIT Press, 2005), 151–152.

58. July 3, 1969 letter from Klüver to Pottasch; Folder 15, Box 45, EAT/GRI.

59. Calvin Tomkins, "Profiles: Woomera Has It!," *New Yorker*, September 21, 1963, 49–14.

60. June 20, 1969 letter from Eugene Draley to Klüver; Folder 15, Box 45, EAT/GRI.

61. "Sigvard Stenlund" in Tomkins's notes; II.B.11, CT/MoMA.

62. Elsa Garmire's description of the mirror is in her essay "An Overview," in Klüver, Martin, and Rose, *Pavilion*, 196–206.

63. Gene Youngblood, "Technology as Empire," *Los Angeles Free Press*, October 3, 1969; this was later reprinted as "The Open Empire," in *Studio International* 179 (April 1970): 178–179.

64. Quote from Eric Saarinen, *The Great Big Mirror Dome* (1969), 16 mm filmstrip, 18:30 min, http://primo.getty.edu/GRI:GETTY_ALMA21133582240001551.

65. “Notes,” October 17, 1969 meeting; Folder 20, Box 49, EAT/GRI.

66. “Exhibit B,” an undated budget but likely mid-1969, gives a cost of some $236,000; another spreadsheet with data from December 1969, increased this to $246,500, which covered the cost of at least one backup mirror in the event that the first was damaged; Folders 10 and 11, Box 43, EAT/GRI.

67. James E. Webb, *Space Age Management: The Large-Scale Approach* (New York: McGraw-Hill, 1969).

68. From Tomkin’s “Osaka Travel Diary,” March 1970; II.B.11, CT, MoMA.

69. Billy Klüver, “1969 Schedule”; BK/JM.

70. Calvin Tomkins, “Onward and Upward with the Arts: E.A.T.,” *New Yorker*, October 3, 1970, 144.

71. Ibid., 108.

72. Ibid., 102.

73. Securing accurate budget estimates is complicated by the myriad drafts and estimates found among the E.A.T. records; these figures come from a June 24, 1969 letter and documents in Folder 10, Box 171, EAT/GRI.

74. April 8, 1970 note from Klüver; Folder 35, Box 43, EAT/GRI.

75. Barbara Rose, “Art as Experience, Environment, Process,” in Klüver, Martin, and Rose, *Pavilion*, 60–104, quote from page 101. Earlier drafts of Rose essay, titled “Art Fiction at the Fair” can be found in Folder 19, Box 2, BR/GRI.

76. Description drawn from Pepsi’s 1970 publicity materials as well as Elsa Garmire’s “E.A.T-Pepsi Pavilion: A Technical Description,” March 1, 1970; both EAT/AAA.

77. A full description of the sound system and Tudor’s use of it is in You Nakai, “Inside-Out: David Tudor’s Composition of the Pepsi Pavilion as Musical Instrument,” *Journal of the American Musical Instrument Society* 43, no. 2 (2017): 171–202.

78. “Live Programming for Pepsi Pavilion: Request for Proposals,” October 15, 1969; EAT/AAA.

79. “Live Programming in the Pepsi Pavilion,” June 10, 1970 announcement; EAT/AAA.

80. August 22, 1969 letter from Pottasch to C. Langhorne Washburn; Folder 12, Box 171, EAT/GRI.

81. March 19, 1970 letter from Pottasch to Klüver; Folder 1, Box 43, EAT/GRI.

82. “Proposals for Live Programming,” in Klüver, Martin, and Rose, *Pavilion*, 285–320.

83. Tomkins’s Osaka diary; II.B.11, CT/MoMA.

84. Ibid.

85. Ibid.

86. Billy Klüver, “Notes,” April 26, 1970; Folder 35, Box 43, EAT/GRI.

87. Calvin Tomkins, “EAT-Pepsi-Crisis,” May 1970 notes; II.B.11, CT/MoMA.

88. In addition to his diary notes, Tomkins’s files contain correspondence pertaining to the E.A.T.-Pepsi split; II.B.11, CT/MoMA. The final agreement is contained in Folder 39, Box 171, EAT/GRI. In the end, Pepsi paid E.A.T. an additional $275,000.

CHAPTER 9

1. Michael Century, “Pathways to Innovation in Digital Culture,” (July 1999).

2. This vignette was first recounted in Matthew Wisnioski’s essay “Centerbeam: Art of the Environment,” in Arindam Dutta, ed., *A Second Modernism: MIT Architecture, and the ‘Techno-Social’*

Moment (Cambridge, MA: MIT Press, 2013), 188, and expanded on by John R. Blakinger in "The Aesthetics of Collaboration: Complicity and Conversion at MIT's Center for Advanced Visual Studies," *Tate Papers*, no. 25 (2016): https://www.tate.org.uk/research/publications/tate-papers/25/aesthetics-of-collaboration, emphasis in original. The original documents related to the incident, which I examined in May 2019, can be found on Reel 5306, GK/AAA.

3. Stewart Brand, *The Media Lab: Inventing the Future at MIT* (New York: Viking, 1987), 83. Surprisingly similar language is found in Edward Dolnick, "Inventing the Future," *New York Times Magazine*, August 23, 1987, 30–33, 41, 59, https://www.nytimes.com/1987/08/23/magazine/inventing-the-future.html. It was with great disappointment, if not surprise, that I discovered the Media Lab's focus on the future also meant a disregard for its past—MIT's official archival collections has a distinct paucity of sources related to the Media Lab's founding and subsequent history. What sources were locatable were found throughout other administrative collections and, ironically, amid materials related to CAVS.

4. Calvin Tomkins, "Automation House," *New Yorker*, March 14, 1970, 30–32; Klüver, stated at an E.A.T. board meeting, December 16, 1970, according to Norma Loewen, "Experiments in Art and Technology: A Descriptive History of the Organization" (PhD diss., New York University, 1975), 200, ProQuest (287918505).

5. July 8, 1976 letter from Malina to John Holloway; Folder 7, Box 7, FM/LOC.

6. Quote comes from Piene's short essay "Technology for Art," which was included in Lawrence Alloway, ed., *5 Artists/5 Technologies: Environmental Light Works by Peter Campus, Harriet Casdin-Silver, Paul Earls, Otto Piene, Alejandro Sina* (Grand Rapids, MI: Grand Rapids Art Museum, 1979); my thanks to Matthew Wisnioski for pointing me toward the original source.

7. Barry M. Katz, *Make It New: The History of Silicon Valley Design* (Cambridge, MA: MIT Press, 2015).

8. Douglas Kahn, "Let Me Hear My Body Talk, My Body Talk," in *Relive: Media Art Histories*, ed. Sean Cubitt and Paul Thomas (Cambridge, MA: MIT Press, 2013), 235–256.

9. My discussion of Kepes and the São Paulo show is indebted to Blakinger's "The Aesthetics of Collaboration."

10. Quote from July 18, 1969 press release draft by Kepes (CAVS/MIT), which was unreleased but later quoted in Grace Glueck, "No Rush for Reservations," *New York Times*, July 6, 1969, https://nyti.ms/1HDKsuA. For MIT's administration's response, see July 8, 1969 memo from Howard Johnson to Jerome Wiesner; Box 39, AC 118, SC/MIT.

11. July 3, 1969 letter from Smithson to Kepes; CAVS/MIT.

12. Grace Glueck, "'Explorations' Spotlights Use of Technology in Art," *New York Times*, April 6, 1970, https://nyti.ms/1ija300; Lawrence Alloway, "Art," *Nation*, April 20, 1970, 476–477, emphasis in original.

13. Jack Burnham, "Software Exhibition," June 10, 1969 memo; Folder 2, SE/JM.

14. "Software," September 14, 1970 press release from the Jewish Museum; Folder 2, SE/JM.

15. Jack Burnham, "Notes on Art and Information Processing," in *Software. Information Technology: Its New Meaning for Art*, ed. Jack Burnham (New York: Jewish Museum, 1970), 10–14.

16. Grace Glueck, "Varied Problems Beset Opening of Jewish Museum's 'Software,'" *New York Times*, September 18, 1970, https://nyti.ms/1kAMykU; and Grace Glueck, "Jewish Museum's 'Software' Confusing," *New York Times*, September 26, 1970, https://nyti.ms/1kAkaz6.

17. "Editorial," *Art News*, December 1970, 23.

18. "Software," September 14, 1970 press release from the Jewish Museum; Folder 2, SE/JM; also Nicholas Negroponte, *Soft Architecture Machines* (Cambridge, MA: MIT Press, 1975), 47; as well as Molly Wright Steenson, *Architectural Intelligence: How Designers and Architects Created the Digital Landscape* (Cambridge, MA: MIT Press, 2017), 184–187.

19. Thomas Hess, “Gerbils Ex Machina,” *Art News*, December 1970, 23.

20. Bob Fiore and Barbara Jarvis, “Software Battle,” *Artforum* 9, no. 3 (1970): 41.

21. Agnes Denes, “Software Battle Continued,” *Artforum* 9, no. 4 (1970): 37.

22. “Willoughby Sharp Interviews Jack Burnham,” *Arts Magazine*, November 1970, 21–23; also, Jack Burnham, “Art and Technology: The Panacea that Failed,” in *Myths of Information: Technology and Postindustrial Culture*, ed. Kathleen Woodward (Madison, WI: Coda, 1980), 200–215.

23. Henry J. Seldis, “Art Mavericks Meet Mahogany Row,” *Los Angeles Times*, May 12, 1971.

24. April 30, 1971 museum press release; AT/LACMA.

25. Lewis Ellmore in Tuchman’s *Art and Technology*, 280; also, Hilton Kramer, “‘Art and Technology’ to Open on Coast,” *New York Times*, May 12, 1971, https://nyti.ms/1kcKEqn.

26. Rauschenberg, quoted in Tuchman’s *Art and Technology*, 285–286.

27. David Antin, “Art and the Corporations,” *Art News* 70, no. 5 (1971): 23–26, 52–56.

28. Antin, “Art and the Corporations,” 23; Jack Burnham, “Corporate Art,” *Artforum* 10, no. 2 (1971): 66–71.

29. Maurice Tuchman, in discussion with the author, August 20, 2013.

30. Leroy F. Aarons, “A Successful Marriage of Art and Technology,” *Washington Post*, June 1, 1971.

31. The sole exception to this homogeneity on the cover of Tuchman’s *Report* was the inclusion of engineer-turned artist Frederick Eversley. Eversley, an African-American born in Brooklyn, was paired with Ampex, an electronics company in the San Francisco Bay area. However, the work he proposed, which involved working with liquid crystals, was unfinished by the time of the 1971 LACMA show. My thanks to Matthew Christensen for drawing my attention to this.

32. Los Angeles Council of Women Artists, “Los Angeles Council of Women Artists Report,” June 15, 1971, http://blogs.getty.edu/pacificstandardtime/explore-the-era/archives/i143/.

33. Dorothy Townsend, “Women Artists Say Museum Discriminates,” *Los Angeles Times*, June 16, 1971.

34. Michael Fallon, *Creating the Future: Art and Los Angeles in the 1970s* (Berkeley, CA: Counterpoint, 2014).

35. “Lasers in L.A.,” *Newsweek*, May 31, 1971, 56.

36. A. Michael Noll, “Art Ex Machina,” *IEEE Student Journal* 8, no. 4 (1970): 10–14.

37. Gordon D. Friedlander, “Art and Technology: A Merger of Disciplines,” *IEEE Spectrum* 6, no. 8 (1969): 60–68, doi:10.1109/MSPEC.1969.5214120.

38. April 8, 1970 letter from Klüver to Donald Kendall; EAT/AAA.

39. Grant D. Taylor, *When the Machine Made Art: The Troubled History of Computer Art* (New York: Bloomsbury, 2014).

40. Gustav Metzger, “Automata in History,” *Studio International* (March 1969): 107–109, https://monoskop.org/images/0/06/Metzger_Gustav_1969_Automata_in_History_part_1.pdf, emphasis in original.

41. Statement by Richard Serra after his participation in LACMA’s Art and Technology Program; quoted in Maurice Tuchman, ed., *Art and Technology: A Report on the Art and Technology Program of the Los Angeles County Museum of Art, 1967–1971* (Los Angeles: Los Angeles County Museum of Art, 1971), 300.

42. Artist’s statement in Tuchman, *Art and Technology*, 286.

43. As recorded in the Q&A part of Klüver’s December 1968 talk, “The Artist and Industry” at MoMA; quoted in Anne Collins Goodyear, “The Relationship of Art to Science and Technology in the United States, 1957–1971: Five Case Studies” (PhD diss., University of Texas at Austin, 2002), 397, ProQuest (305503573).

44. The Smithsonian American Art Museum made this abundantly clear in its 2019 exhibition "Artists Respond: American Art and the Vietnam War, 1965–1975"; see the accompanying catalog, Melissa Ho, ed., *Artists Respond: American Art and the Vietnam War, 1965–1975* (Princeton: Princeton University Press, 2019).

45. Jack Burnham, "Corporate Art," *Artforum* 10, no. 2 (1971): 66–71, https://www.artforum.com/print/197108/the-art-and-technology-exhibition-at-the-los-angeles-county-museum-two-views-corporate-art-38028.

46. Quotes from Max Kozloff, "The Multimillion Dollar Art Boondoggle," *Artforum* 10, no. 2 (1971): 72–76, https://www.artforum.com/print/197108/the-multimillion-dollar-art-boondoggle-34013; Amy Goldin, "Art and Technology in a Social Vacuum," *Art in America* 60, no. 2 (1972): 46–51.

47. Kozloff, "The Multimillion Dollar Art Boondoggle," 76.

48. Tuchman, *Art and Technology*, 17.

49. Maurice Tuchman, in discussion with the author, August 20, 2013.

50. Jonathan Benthall, *Science and Technology in Art Today* (New York: Praeger, 1972); Benthall's recollections are in his essay "Technological Art and *Studio International*'s Eclectic Vanguardism," *Interdisciplinary Science Reviews* 42, no. 1–2 (2017): 79–92, doi:10.1080/03080188.2017.1297154.

51. Anne Collins Goodyear, "From Technophilia to Technophobia: The Impact of the Vietnam War on the Reception of 'Art and Technology,'" *Leonardo* 41, no. 2 (2008): 169–173, https://www.muse.jhu.edu/article/236382; a counterpoint can be found in David Kaiser and W. Patrick McCray, eds., *Groovy Science: Knowledge, Innovation, and American Counterculture* (Chicago: University of Chicago Press, 2016), doi:10.7208/chicago/9780226373072.001.0001.

52. Marc Levinson, *An Extraordinary Time: The End of the Postwar Boom and the Return of the Ordinary Economy* (New York: Basic, 2016).

53. National Research Council, *Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future* (Washington, DC: National Academy Press, 1985), doi:10.17226/582.

54. Pete Barrer, "Engineers in the Working Class," *Science for the People* 3, no. 4 (September 1971): 9, 11–13, https://archive.scienceforthepeople.org/vol-3/v3n4/engineers-in-the-working-class/.

55. David Kaiser, "Booms, Busts, and the World of Ideas: Enrollment Pressure and the Challenge of Specialization," *Osiris* 27, no. 1 (2012): 276–302.

56. Earl Gottschalk, "Aerospace Layoffs," *Los Angeles Times*, May 2, 1971.

57. Woody Vasulka and Peter Weibel, eds., *Buffalo Heads: Media Study, Media Practice, Media Pioneers, 1973–1990* (Cambridge, MA: MIT Press, 2008).

58. December 16, 1970 letter from Wise.

59. Obviously, video art, even just in the 1970s, is a very well-researched topic. Two books especially useful to me were Deirdre Boyle, *Subject to Change: Guerrilla Television Revisited* (New York: Oxford University Press, 1997) and Chris Meigh-Andrews, *A History of Video Art* (New York: Bloomsbury, 2014). For philanthropic support, see Marita Sturken, "Private Money and Personal Influence," *Afterimage* 14, no. 6 (January 1987): 8–15.

60. The original statement is reproduced in Melissa Chiu and Michelle Yun, eds., *Nam June Paik: Becoming Robot* (New York: Asia Society, 2014), 68.

61. Peter Sachs Collopy, "Video Synthesizers: From Analog Computing to Digital Art," *IEEE Annals of the History of Computing* 36, no. 4 (October/December 2014): 75–86, doi:10.1109/MAHC.2014.62.

62. Calvin Tomkins, "Video Visionary," *New Yorker*, May 5, 1975, 44–79.

63. See, for example, Diane Kirkpatrick, "Sonia Landy Sheridan and the Evolution of Her Generative Systems Program," *Visual Resources* 22, no. 4 (2006): 343–361, doi:10.1080/01973760601010325.

64. Roger. F. Malina, “Looking to the Future,” *Leonardo* 26, no. 1 (1993): 1, https://www.muse.jhu.edu/article/606935.

65. See short biographical sketch at the end of John F. Forkner, “Computer Generation of Null Masks for Ronchi Lens Tests,” *Optical Engineering* 39, no. 7 (2000): 1840–1844, doi:10.1117/1.602566.

66. *SeaLight: News and Information for the Unitarian Universalist Fellowship of Laguna Beach* 4, no. 7 (2004): 2; copy in the author’s files.

67. Kenneth Herman, “UCSD’s Magical Mystical Tour Offers Journey into Rarely Traveled Spheres,” *Los Angeles Times*, November 20, 1987, https://www.latimes.com/archives/la-xpm-1987-11-20-ca-15343-story.html.

68. Robert Whitman, in conversation with the author, December 31, 2014.

69. Art and Technology, Inc. existed for a few years, eventually having several dozen artists and engineers as members. Robert Kieronski, in discussion with the author, June 19, 2015; see also *Lumion*, http://www.lumion.net/home.php.

70. Anna Kisselgoff, “Brave New World of Movement-Activated Sound,” *New York Times*, March 16, 1989, https://nyti.ms/29yFemE; Alan M. Kriegsman, “‘Astral’: Starry Night: Trisha Brown’s Monumental Collaboration,” *Washington Post*, May 15, 1991.

71. “Projects Outside Art: An Exhibition of Realizable Projects in the Environment,” undated (late 1970) press release; EAT/AAA.

72. “City Agriculture,” September 3, 1970 proposal; EAT/AAA.

73. Daniel Grant, “Social Practice Degrees Take Art to a Communal Level,” *New York Times*, February 5, 2016, https://nyti.ms/1X8O5wb.

74. “Children and Communication,” September 24, 1970 proposal; EAT/AAA.

75. “Children and Communication,” May 1, 1971 report; EAT/AAA. Also, Michelle Kuo, “No Limits,” in *E.A.T.: Experiments in Art and Technology*, ed. Sabine Breitwieser (Salzburg, Austria: Museum der Moderne, 2015), 163–181.

76. Loewen, “Experiments in Art and Technology,” 217.

77. Billy Klüver and Julie Martin, *Kiki’s Paris: Artists and Lovers, 1900–1930* (New York: Abrams, 1994).

78. Kay Larson, “Billy Klüver, 76, an Engineer Who Collaborated with Artists,” *New York Times*, January 13, 2004, https://www.nytimes.com/2004/01/13/arts/billy-kluver-76-an-engineer-who-collaborated-with-artists.html; John Rockwell, “The Man Who Made a Match of Technology and Art,” *New York Times*, January 23, 2004, https://www.nytimes.com/2004/01/23/movies/reverberations-the-man-who-made-a-match-of-technology-and-art.html.

79. “It’s 2001 and a “Drugless High’ as Ivan Dryer Sets Laser Beams to Music,” *People*, January 26, 1976, http://www.people.com/people/archive/article/0,,20066089,00.html.

80. Ivan Dryer, “Applications Pioneer Interview: Ivan Dryer,” *Laser and Applications*, October 1986, 53–58.

81. This was not the first public laser light show, however. In May 1969, for example, composer and instrument builder Lowell Cross, along with composer David Tudor and physicist Carson Jeffries, presented an outdoor laser light show at Mills College in Oakland, California. A laser system Cross and Jeffries designed was incorporated into the Pepsi Pavilion and, in a 1981 article, Cross intimated that Garmire “disclosed the techniques” of his system to Dryer as the basis for Laserium; Lowell Cross, “The Audio Control of Laser Displays,” *db* 15, no. 7 (1981): 30–41.

82. “Mayor Proclaims ‘Laserium Month,’” *Los Angeles Times*, December 25, 1974.

83. Dale Pelton, “‘Death of the Red Planet’ Filmed in Laser Images,” *American Cinematographer* 54, no. 7 (1973): 842–843, 902, 911.

84. Interview with Elsa Garmire, in *Peer Review: Hybrid Collaborations in the 1960s & 70s*, produced by Steven Duval and Ryan Waggoner (Lawrence: Spencer Museum of Art, University of Kansas, 2015) DVD; transcript in the author's collection.

85. Dan Slater, Ivan M. Dryer, and Charles W. McDonald, Laser Light Image Generator, US Patent 4,006,970, filed July 14, 1975, issued February 8, 1977, https://patents.google.com/patent/US4006970A/en?oq=US+Patent+4%2c006%2c970. (Charles McDonald's name appears incorrectly in the 1977 US Patent paperwork, where it is spelled "McDanald.")

86. Iwan Rhys Morus, *Frankenstein's Children: Electricity, Exhibition, and Experiment in Early-Nineteenth Century London* (Princeton: Princeton University Press, 1998); and Jordan D. Marché, *Theatres of Time and Space: American Planetaria, 1930–1970* (New Brunswick, NJ: Rutgers University Press, 2005).

87. See, for example, "Ivan Dryer, 1939–2017," *ILDA: International Laser Display Association*, http://www.ilda.com/ivandryer.html.

88. See "New Grants Fund Film Preservation Projects at NYU," *NYU | Tisch*, June 14, 2017, https://tisch.nyu.edu/cinema-studies/news/bill-brand-nfpf-2017.

89. Andrew Kagan, "Laserium: New Light on an Ancient Vision," *Arts Magazine*, March 1978, 126–131.

90. Nam June Paik, "Bill Clinton Stole My Idea," in *Nam June Paik: Eine Database*, ed. Klaus Bußmann and Florian Matzner (Stuttgart, Germany: Deutscher Pavillion, 1993), 110–116.

91. Atsushi Akera and Bruce Seely, "A Historical Survey of the Structural Changes in the American System of Engineering Education," in *International Perspectives on Engineering Education: Engineering Education and Practice in Context*, ed. Steen Hyldgaard Christensen et al. (New York: Springer, 2015), 1:7–32, doi:10.1007/978-3-319-16169-3_1.

92. Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott, and Martin Trow, *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies* (London: SAGE, 1994).

93. Dian O. Belanger, *Enabling American Innovation: Engineering and the National Science Foundation* (West Lafayette, IN: Purdue University Press, 1998).

94. An overview of these trends can be seen in the above-mentioned 1985 National Research Council report, *Engineering Education and Practice in the United States*.

95. Essays in Dutta, *A Second Modernism* explore this shift.

96. *Centerbeam* debuted the year before in Kassel, Germany at documenta 6. Otto Piene and Elizabeth Goldring, eds., *Centerbeam* (Cambridge, MA: MIT Press, 1980) describes the show while Matthew Wisnioski's essay "Centerbeam: Art of the Environment," in Dutta, *A Second Modernism*, 188–225, provides analysis.

97. Description drawn from Brand, *The Media Lab*, 6–8.

98. A wonderfully researched exposition of the Architecture Machine Group's activities is in chapter 6 of Steenson's *Architectural Intelligence*.

99. Brand, *The Media Lab*, 162.

100. An excellent, though currently unpublished essay that looks at this process is curator Meg Rotzel's "The Media Lab That Wasn't," (2009), which she kindly shared with me.

101. Otto Piene, December 19, 1977 memo regarding "Arts Facilities Meeting"; CAVS/MIT.

102. MIT Committee on the Visual Arts, *Artists and Architects Collaborate: Designing the Wiesner Building* (Cambridge, MA: Committee on the Visual Arts, 1985).

103. Richard Leacock and Nicholas Negroponte, "Arts Facility Packaging," December 27, 1977 memo to William Porter; CAVS/MIT.

104. Term from Meg Rotzel's "The Media Lab That Wasn't."

105. Otto Piene, "Practice, Research, and Education in the Arts," December 9, 1982 letter and proposal to John de Monchaux; CAVS/MIT.

106. "A New Center for Arts and Media Technology," July 2, 1982 draft proposal; CAVS/MIT.

107. Quotes from "A Proposal for A Center for Media Studies," undated draft, likely 1979 and, "A New Center for Arts and Media Technology," July 2, 1982 draft proposal; CAVS/MIT.

108. March 17, 1983 notes of AMT/CAVS meeting; CAVS/MIT.

109. February 11, 1986 letters between Paul Gray, John Deutch, and John de Monchaux and accompanying budget discussions with Piene; Box 19, AC 180, SC/MIT.

110. "Ad Hoc Committee to Review the Creative Arts at MIT: Report to the Provost," July 1987; CAVS/MIT.

111. Nicholas Negroponte, "Media Arts and Science Degree Programs and Media Laboratory: Five Year Plan, 1986–1991" January 17, 1986; Box 15, AC 400, SC/MIT.

112. An article detailing MIT's current relationship with the government of Saudi Arabia notes the Media Lab specifically, see Michael Sokolove, "Why Is There So Much Saudi Money in American Universities?," *New York Times Magazine*, July 3, 2019, 22.

113. Michael Naimark, *Truth, Beauty, Freedom, and Money: Technology-Based Art and the Dynamics of Sustainability*, a report for *Leonardo Journal* supported by the Rockefeller Foundation, May 2003, revised February 2004, https://www.issuelab.org/resource/truth-beauty-freedom-and-money-technology-based-art-and-the-dynamics-of-sustainability.html.

114. Quote from a July 15, 2002 press release titled "Leonardo/ISAST Investigates Sustainable Art and Technology Research Lab," http://web.archive.org/web/20130205232547/http://www.leonardo.info/isast/artslab.html.

115. For example, the phrase "economic competitiveness" (according to Google's Ngram Viewer) began to spike around 1990 and peaked between 1995 and 2000. Also see Paul Krugman, *Peddling Prosperity: Economic Sense and Nonsense in an Age of Diminished Expectations* (New York: Norton, 1995), esp. chapter 10.

116. Peter Ellyard, "Artists, Technology, and Economic Survival," *Artlink* 7, no. 2/3 (1987): 27–28.

117. John Seely Brown, introduction to *Art and Innovation: The Xerox PARC Artist-in-Residence Program,* ed. Craig Harris (Cambridge, MA: MIT Press, 1999), vi–viii.

118. Rich Gold, "PAIR: PARC Artists-In-Residence Program," November 1992 talk; Folder 17, Box 37, RG/SU; Anna Novakov, "A Bucolic Honeymoon for Art and Science," *New York Times*, August 15, 1999, https://www.nytimes.com/1999/08/15/arts/artarchitecture-a-bucolic-honeymoon-for-art-and-science.html.

119. Michael Century, *Pathways to Innovation in Digital Culture* (Montreal, Canada: Centre for Research on Canadian Cultural Industries and Institutions McGill University/Next Century Consultants, July, 1999; Troy, NY: Department of the Arts Rensselaer Polytechnic Institute, Update October 2013), http://www.nextcentury.ca/PathwaysToInnovationInDigitalCulture.pdf.

120. Thomas A. Bass, "Think Tanked," *Wired*, December 1, 1999, https://www.wired.com/1999/12/interval/.

121. Michael Naimark, "History of Institutions," October 1, 2005, Soundcloud audio, 14:55, audio file 67, address at REFRESH, an international new media conference held at Banff, Canada, https://soundcloud.com/user-527330471/sets/bnmi1k5u-refresh.

122. The story of Stanford, CCRMA, and Chowning is wonderfully told in Andrew J. Nelson's *The Sound of Innovation: Stanford and the Computer Music Revolution* (Cambridge, MA: MIT Press, 2015).

123. The project was initiated by funding from the Rockefeller Foundation and its official report appeared as National Research Council, *Beyond Productivity: Information Technology, Innovation, and Creativity* (Washington, DC: National Academy Press, 2003), doi:10.17226/10671.

124. Kevin Kelly, "The Third Culture," *Science* 279, no. 5353 (1998): 992–993, doi:10.1126/science.279.5353.992. Kelly's essay itself was a reprise of an idea from his literary agent John Brockman (who was also a figure in the late 1960s "intermedia" art world of New York City); John Brockman, *Third Culture: Beyond the Scientific Revolution* (New York: Simon and Schuster, 1996).

125. Fred Turner, "Burning Man at Google: A Cultural Infrastructure for New Media Production," *New Media and Society* 11, no. 1–2 (2009): 73–94.

126. A 2004 survey initially prepared by Michael Naimark and Mark Tribe counted over fifty of these, see Stewart Mader, last edited by Mark Tribe on May 11, 2014, "Directory of Art & Technology Programs: A Wiki Directory of Academic Art and Technology Programs," https://web.archive.org/web/20150222222121/https://wiki.brown.edu/confluence/pages/viewpage.action?pageId=13017#DirectoryofArt%26TechnologyPrograms-StevensInstituteofTechnology%3AArt%26TechnologyProgram.

127. John Markoff, "A Silicon Valley Laboratory Shuts Down," *New York Times*, April 22, 2000, https://www.nytimes.com/2000/04/22/business/a-silicon-valley-laboratory-shuts-down.html. Our understanding of the history of Interval Research is hindered by the nondisclosure forms almost all employees were required to sign. More serious was the reclamation, in 2010, by Allen's lawyers (acting on behalf of his company, Vulcan) of Interval materials that had been donated to Stanford University's Special Collections, due to patent litigation; see, for example, Dionne Searcey, "Microsoft Co-Founder Launches Patent War," *Wall Street Journal*, August 28, 2010, https://www.wsj.com/articles/SB10001424052748703294904575385241453119382. The US Supreme Court rejected Allen's claims in 2015 but the documents associated with Interval remain unavailable to researchers as of this writing.

128. Anecdotes and reports prepared in the wake of the dot-com boom, such as National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, *Pan-Organizational Summit on the U.S. Science and Engineering Workforce* (Washington, DC: National Academies Press, 2003), doi:10.17226/10727, give a sense of this change.

CONCLUSION

1. From Steve Jobs's introduction of the iPad 2 on March 2, 2011 at the Yerba Buena Center for the Arts in San Francisco. Jobs passed away in November 2011. See Tim Carmody, "Without Jobs as CEO, Who Speaks for the Arts at Apple?," *Wired*, August 29, 2011, https://www.wired.com/2011/08/apple-liberal-arts/.

2. See, for example, Andrew Goldsmith, "The SciArt Movement: Why Facebook, MIT, and Autodesk Use Art to Drive Innovation*," Leadership Strategy* (blog), *Forbes*, July 23, 2018, https://www.forbes.com/sites/andrewgoldsmith/2018/07/23/the-sciart-movement-why-facebook-mit-and-autodesk-use-art-to-drive-innovation/#4a5f48523911.

3. Obviously, the literature on this topic is vast and growing; a historical perspective is Adam Tooze, *Crashed: How a Decade of Financial Crises Changed the World* (New York: Viking, 2018).

4. See, for example, the *New York Times*' special section, Crisis and Consequences, *New York Times*, https://nyti.ms/2MlM5k3.

5. Laura Pappano, "The Year of the MOOC," *New York Times*, November 2, 2012, https://nyti.ms/2kBM8OV.

6. Data from Joshua Wright, "STEM Majors Are Accelerating in Every State, Just as Humanities Degrees Are Declining," *Emsi* (blog), September 1, 2017, https://www.economicmodeling.com/2017/09/01/stem-majors-accelerating-every-state-just-humanities-degrees-declining/ as well as Scott Jaschik, "The STEM Enrollment Boom," *Inside Higher Ed* (blog), April 7, 2014, https://www.insidehighered.com/news/2014/04/07/study-finds-increased-stem-enrollment-recession. Benjamin Schmidt has provided several excellent analyses of this trend. See, for example, Benjamin Schmidt, "The Humanities Are in Crisis," *Ideas* (blog) *Atlantic*, August 23, 2018, https://www.theatlantic.com/ideas/archive/2018/08/the-humanities-face-a-crisisof-confidence/567565/.

7. Michael Paulson, "Sorry About That: Wells Fargo to End Ads Suggesting Science Over Arts," *New York Times*, September 5, 2016, https://nyti.ms/2cn0Ke4.

8. See, for example, Eric Hayot, "The Humanities as We Know Them Are Doomed. Now What?," *Chronicle Review*, July 1, 2018, https://www.chronicle.com/article/The-Humanities-as-We-Know-Them/243769.

9. For example, Kevin Kiley, "Another Liberal Arts Critic," *Inside Higher Ed* (blog), January 30, 2013, https://www.insidehighered.com/news/2013/01/30/north-carolina-governor-joins-chorus-republicans-critical-liberal-arts. This phenomenon wasn't confined just to the United States; see Vanessa Barbara, "Who Needs the Humanities When You Have Jair Bolsonaro," *New York Times*, June 12, 2019, https://nyti.ms/2X5ORmW.

10. See Christopher Newfield's work, which offered considerable data that the humanities actually help support STEM fields, in books like *The Great Mistake: How We Wrecked Public Universities and How We Can Fix Them* (Baltimore: Johns Hopkins University Press, 2016).

11. Louis Hyman, *Temp: How American Work, American Business, and the American Dream Became Temporary* (New York: Viking, 2018).

12. Nancy Cole, "Schools Embrace Makerspaces, and Parents Can Too," *Early Learners* (blog), *Parent Today*, February 7, 2017, https://www.parenttoday.org/schools-embrace-makerspaces-and-parents-can-too/. For context, see Fred Turner, "Millenarian Tinkering: The Puritan Roots of the Maker Movement," *Technology and Culture* 59, no. 4, suppl. (2018): S160–S182, doi:10.1353/tech.2018.0153.

13. Susan Currie Sivek, "'We All Need a Showing of Hands': Technological Utopianism in MAKE Magazine," *Journal of Communication Inquiry* 35, no. 3 (2011): 187–209, doi:10.1177/0196859911410317.

14. Tom Nardi, "Maker Media Ceases Operations," *Hackaday* (blog), June 7, 2019, https://hackaday.com/2019/06/07/maker-media-ceases-operations/. As of January 2020, the operation appears to have been rejuvenated with a different structure; https://community.make.co/.

15. Matthew Wisnioski, Eric S. Hintz, and Marie Stettler Kleine, eds., *Does America Need More Innovators?* (Cambridge, MA: MIT Press, 2019).

16. Biographical information comes from Claudia Dreifus, "A Conversation with John Maeda: When MIT Artist Shouts, His 'Painting' Listens," *New York Times*, July 27, 1999, https://www.nytimes.com/1999/07/27/science/a-conversation-with-john-maeda-when-mit-artist-shouts-his-painting-listens.html.

17. Bridging STEM to STEAM: Developing New Frameworks for Art/Science Pedagogy (Providence, RI: Rhode Island School of Design, January 20–21, 2011); copy in the author's files.

18. "Integrating Education in the Arts and Humanities with Education in Science, Engineering, Technology, and Medicine," December 2, 2015 workshop; notes and materials in the author's files.

19. The Wellcome Trust's program ran from 1996 to 2006. One recent appraisal is Charlotte Sleigh and Sarah Craske, "Art and Science in the UK: A Brief History and Critical Reflection," *Interdisciplinary Science Reviews* 42, no. 4 (2017): 313–330, doi:10.1080/03080188.2017.1381223.

20. Paul Glinkowski and Anne Bamford, *Insight and Exchange: An Evaluation of the Wellcome Trust's Sciart Programme* (London: Wellcome Trust, 2009).

21. See, for instance, "What Letter Should We Add to STEM?," *The Big Question* (blog), *Atlantic*, October 8, 2014, https://www.theatlantic.com/video/index/381238/what-letter-should-we-add-to-stem/; "WEF Davos 2014 Hub Culture Interview with John Maeda," YouTube video, 3:24, from an interview at Hub Culture Davos Pavilion, posted by "Hub Culture," January 25, 2014, https://youtu.be/D2VlWDG8I3k; and "John Madea: 'STEM to STEAM: The Meaning of Innovation,' Talks at Google," YouTube video, 53:55, posted by "Talks at Google," December 7, 2011, https://youtu.be/0yc-_Ei2Yto.

22. "Reps. Bonamici and Schock Announce Bipartisan Congressional STEAM Caucus," February 14, 2013 press release, https://bonamici.house.gov/press-release/reps-bonamici-and-schock-announce-bipartisan-congressional-steam-caucus.

23. Expressing the Sense of the House of Representatives That Adding Art and Design into Federal Programs That Target the Science, Technology, Engineering, and Mathematics (STEM) Fields Encourages Innovation and Economic Growth in the United States, H.R. 51, 113th Cong. (February 4, 2013), https://www.congress.gov/bill/113th-congress/house-resolution/51/actions.

24. David J. Skorton, in discussion with the author, December 11, 2018. However, when I spoke informally with Skorton, he was quite clear of the potential pitfalls of taking an overly instrumental view toward the arts while noting it was too soon to see what effects the report might have.

25. "War on Tyranny Urged by Einstein," *New York Times*, October 11, 1937, https://nyti.ms/1MXLnIW.

26. National Academies of Sciences, Engineering, and Medicine, *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree* (Washington, DC: National Academies Press, 2018), doi:10.17226/24988. The Nobel-creativity connection comes from the work of Robert and Michèlle Root-Bernstein, such as *Spark of Genius: The Thirteen Thinking Tools of the World's Most Creative People* (New York: Houghton Mifflin, 1999).

27. Published as Ben Shneiderman, "Creativity and Collaboration: Revisiting Cybernetic Serendipity," *PNAS* 116, no. 6 (2019): 1837–1843, doi:10.1073/pnas.1807200116.

28. A cursory search for "STEM to STEAM" in JSTOR, for example, revealed only two examples, both in *Art Education*.

29. Margaret A. Weitekamp, "The Image of Scientists in the *Big Bang Theory*," *Physics Today* 70, no. 1 (2017): 40–48, doi:10.1063/PT.3.3427.

30. Several colleagues, including Amy E. Slaton, Alex Wellerstein, Lee Vinsel, Douglas Kahn, and Melinda Gormley, graciously provided input for my thoughts here.

31. Billy Klüver, "The Great Northeastern Power Failure," January 28, 1966 talk; EAT/AAA.

32. Megan O'Grady, "Art for a Post-Surveillance Age," *New York Times Style Magazine*, August 29, 2017, https://nyti.ms/2vGl5DH.

33. Not surprisingly, this doesn't reproduce well. A version of the May 2011 cover can be viewed at: https://www.artforum.com/print/201105. See also Pamela M. Lee, "Open Secret: The Work of Art between Disclosure and Redaction," *Artforum*, May 2011, https://www.artforum.com/print/201105/open-secret-the-work-of-art-between-disclosure-and-redaction-28060; and Pamela M. Lee, *Think Tank Aesthetics: Midcentury Modernism, the Cold War, and the Neoliberal Present* (Cambridge, MA: MIT Press, 2020).

34. Tim Sohn, "Trevor Paglen Plumbs the Internet," *New Yorker*, September 22, 2015, https://www.newyorker.com/tech/annals-of-technology/trevor-paglen-plumbs-the-internet-at-metro-pictures-gallery.

35. Jonah Weiner, "Prying Eyes," *New Yorker*, October 15, 2012, https://www.newyorker.com/magazine/2012/10/22/prying-eyes.

36. A fuller description is in Trevor Paglen and Jacob Appelbaum, *Autonomy Cube* (Berlin: Revolver Publishing, 2016).

37. Trevor Paglen, "Clarice Smith Distinguished Lecture" (Smithsonian American Art Museum, Washington, DC, September 9, 2015), https://americanart.si.edu/videos/clarice-smith-distinguished-lecture-artist-trevor-paglen-153926.

38. Jori Finkel, "Shutdown Leaves Uninflated Space Sculpture Circling in Orbit," *New York Times*, January 25, 2019, https://nyti.ms/2HvWFYJ.

39. Naomi Rea, "Artist Trevor Paglen's $1.5 Million 'Orbital Reflector' is Officially Lost in Space Thanks to President Trump's Government Shutdown," *artnet*, May 2, 2019, https://news.artnet.com/art-world/trevor-paglen-orbital-reflector-lost-space-1533073.

40. Andrea Chang, "Technology and Art Converge in LACMA Program," *Los Angeles Times*, December 11, 2013.

41. Randy Kennedy, "Art and Technology, Together Again, at Los Angeles County Museum of Art," *ArtsBeat* (blog), *New York Times*, December 9, 2013, https://artsbeat.blogs.nytimes.com/2013/12/09/art-and-technology-together-again-at-los-angeles-county-museum-of-art/. An excellent critique of the Art + Technology Lab and other recent efforts is John Beck and Ryan Bishop, "The Return of the Art and Technology Lab," *Cultural Politics* 14, no. 2 (2018): 225–243, doi:10.1215/17432197-6609102.

42. Joel Ferree, in discussion with the author, October 8, 2018.

43. Annina Rüst, "A Piece of the Pie Chart: Feminist Robotics," *Leonardo* 47, no. 4 (2014): 360–366, doi:10.1162/LEON_a_00841.

44. "Art, Technology, and Collaboration," *Unframed* (blog), LACMA, July 8, 2015, https://unframed.lacma.org/2015/07/08/art-technology-and-collaboration; also, John Craig Freeman, "Emergent Technology as Art Practice and Public Art as Intervention," *Leonardo Electronic Almanac* 21, no. 1 (2016): 60–69, https://www.leonardo.info/sites/default/files/leavol21no1_la_replay_john-craig-freeman.pdf.

45. Amy Heibel, in discussion with the author, October 17, 2018.

46. See the website for *NEAT: New Experiments in Art and Technology*, http://neat.thecjm.org/.

47. David Kushner, "The Making of Arduino," *IEEE Spectrum*, October 26, 2011, https://spectrum.ieee.org/geek-life/hands-on/the-making-of-arduino.

48. Renny Pritikin, "Curatorial Notes," http://neat.thecjm.org/pritikin/.

49. Casey Lesser, "What's It Like to Be an Artist in Residence at Facebook?," *Artsy*, October 31, 2017, https://www.artsy.net/article/artsy-editorial-artist-residence-facebook.

50. Bennett, quoted in Fred Turner, "The Arts at Facebook: An Aesthetic Infrastructure for Surveillance," *Poetics* 67 (April 2018): 53–62, doi:10.1016/j.poetic.2018.03.003.

51. Edward A. Shanken, "Artists in Industry and the Academy: Collaborative Research, Interdisciplinary Scholarship, and the Creation and Interpretation of Hybrid Forms," *Leonardo* 38, no. 5 (2005): 415–418, doi:10.1162/leon.2005.38.5.415.

52. Marcus Weldon, "Welcome Address," July 27, 2016; copy in author's possession.

53. See, for example, "Experiments in Art and Technology," Nokia Bell Labs, https://www.bell-labs.com/programs/experiments-art-and-technology/; and Marcus Weldon, "Nokia Bell Labs and New Museum: Announce Partnership to Support Art and Technology Collaboration," https://us1.campaign-archive.com/?u=c6bf7cce2a64f8749424edd72&id=cc636dad65.

54. Deirdre Fernandes, "A Meeting with Jeffrey Epstein Led to a Gift—and, Now, Regrets," *Boston Globe*, September 13, 2019, https://www.bostonglobe.com/metro/2019/09/13/meeting-with-epstein-led-gift-and-now-regrets/0SPYm0hSg8iNh3JdDwPICP/story.html.

55. For example, Tiffany Hsu, Marc Tracy, and Erin Griffin, "Jeffrey Epstein's Donations Create a Schism at M.I.T.'s Revered Media Lab," *New York Times*, September 5, 2019, https://nyti.ms/2LmjFZL. The day after this article appeared, another piece in the *New Yorker*—Ronan Farrow, "How an Élite University Research Center Concealed Its Relationship with Jeffrey Epstein," https://www.newyorker.com/news/news-desk/how-an-elite-university-research-center-concealed-its-relationship-with-jeffrey-epstein—was published online, which presented more evidence of the Media Lab's questionable financial activity. Ito resigned as its director the following day.

56. Journal data provided to the author in October 2018 by Erica Hruby, *Leonardo*'s managing editor.

57. Gabe Cohn, "Up for Bid, AI Art Signed 'Algorithm,'" *New York Times*, October 22, 2018, https://nyti.ms/2R99M1S. Accompanying this was a burst of articles examining what artificial intelligence might mean for the art world such as Susan Delson, "Blurring the Physical and Digital Worlds," *Wall Street Journal*, March 15, 2019, https://www.wsj.com/articles/blurring-the-physical-and-digital-worlds-11552656677; and Ian Bogost, "The AI-Art Gold Rush Is Here," *Atlantic*, March 6, 2019, https://www.theatlantic.com/technology/archive/2019/03/ai-created-art-invades-chelsea-gallery-scene/584134/.

58. Information of Ai-Da is available at *Ai-DaRobot*, https://www.ai-darobot.com. Reactions to the Oxford exhibit include Chiara Ambrosio, "Unsettling Robots and the Future of Art," *Science* 365, no. 6448 (2019): 38–39, doi:10.1126/science.aay1956; and Naomi Rea, "A Gallery Has Sold More Than $1 Million in Art Made by an Android, But Collectors Are Buying into a Sexist Fantasy," *artnet*, June 6, 2019, https://news.artnet.com/opinion/artificial-intelligence-robot-artist-ai-da-1566580.

59. "Getty Announces New Pacific Standard Time Collaboration Exploring the Intersection of Art and Science in a Global Dimension," June 26, 2019 press release, http://news.getty.edu/pst-artxsciencexla.htm.

60. James Seawright, "Phenomenal Art: Form, Idea, and Technique," in *On the Future of Art*, ed. Edward Fry (New York: Viking, 1970), 77–94. Seawright was an engineering officer in the US Navy who also studied physics in college before becoming an artist.

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