

Michael Century

Northern Sparks

**Innovation, Technology Policy,
and the Arts in Canada from
Expo 67 to the Internet Age**



Northern Sparks

Leonardo

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Northern Sparks

**Innovation, Technology Policy, and the Arts in Canada
from Expo 67 to the Internet Age**

Michael Century

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For Barbara Todd

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Series Foreword

Leonardo/The International Society for the Arts, Sciences and Technology fosters transformation at the nexus of art, science, and technology because complex problems require creative solutions. The Leonardo book series shares these aims of artistic and scientific experimentation, publishing books to define problems and discover solutions, to critique old knowledge and create the new.

In the early twentieth century, the arts and sciences seemed to interact instinctively. Modern art and modern poetry were automatically associated with relativity and quantum physics, as if the two were expressions of a single zeitgeist. At the end of the Second World War, once again it seemed perfectly clear that avant-garde artists, architects, and social planners would join cyberneticists and information theorists to address the problems of the new world order and to create new ways of depicting and understanding its complexity through shared experiences of elegance and experiment. Throughout the twentieth century, the modern constantly mixed art and science.

In the twenty-first century, though, we are no longer modern but contemporary, and now the wedge between art and science that C. P. Snow saw emerging in the 1950s has turned into a culture war. Governments prefer science to arts education, yet stand accused of ignoring or manipulating science. The arts struggle to justify themselves in terms of economic or communicative efficiency that devalues their highest aspirations. And yet never before have artists, scientists, and technologists worked together so closely to create individual and collective works of cultural power and intellectual grace. *Leonardo* looks beyond predicting dangers and challenges, beyond

even planning for the unpredictable. The series publishes books that are both timely and of enduring value—books that address the perils of our time, while also exploring new forms of beauty and understanding.

Sean Cubitt, Editor-in-Chief, Leonardo Book Series

Erica Hruby, Editorial Director, Leonardo/ISAST

Preface

As an American growing up in western Canada during the 1960s, in the shadow of the oil wells that brought my family there in the first place, my prevailing orientation was to the south. I was drawn more to the revolutionary allures of America, awful yet compelling in those turbulent years. When my liberal parents chose to keep us in Canada during the height of the Vietnam War, I initially felt sidelined, remote from the heart of the action. Thus it was with the fervor of a convert that I later adopted a way of identifying as a Canadian in relational terms, ever comparing, never fixed, with a dual sense of proximity and distance born out of my own initial ambivalence.

In a similar way, this book reveals how a uniquely Canadian story can provide a fresh angle on a well-established narrative. *Northern Sparks* is about the intersecting histories of technological innovation, new media arts, and government policies in Canada from the 1960s to the early 1990s. It portrays this period as an “episode of light” sparked by an intense national awakening following the international success of the media-rich 1967 world’s fair in Montréal during the nation’s centennial year. The opening conjuncture of the arts, technology, and political consciousness elicited an exceptionally broad range of outcomes that go beyond notable artworks or new technological systems and tools. Poised as a “counter-environment” to the great powers, in Marshall McLuhan’s phrase, Canada’s unique experience of the transitional decades into the information age was grounded in a technological ethos that emphasized sensorial immediacy, embodied interaction, and improvisatory expression. This alternative ethos was situated between a pair of distinct yet inextricably bound forces, one national-political and proper to Canada, the other techno-mediatic and global in

scale. The unraveling of these forces by the late millennium reveals innovation itself as a complexly drawn process comprised of multiple layers with fluctuating degrees of synchronization.

I am grateful to the many individuals who generously offered their insights and encouragement over the course of this book's long gestation. Justin Sully provided the indispensable perspective as well as editorial acumen needed to complete it. For the conversations that helped launch the project, I thank Thierry Bardini, Bill Buxton, Robin Mansell, David Neice, B. W. Powe, Catherine Richards, Joan Shigekawa, Ed Steinmueller, and Will Straw. McGill University's Centre for Research on Canadian Cultural Industries and Institutions gave me the institutional home that incubated the project, Hexagram at Concordia University supported a research residency, and the School of Humanities, Arts and Social Sciences at Rensselaer Polytechnic Institute provided a conducive interdisciplinary milieu in which to combine my interests in new media history and theory with policy studies. Nancy Campbell, Tom Sherman, Ron Graham, Barry Truax, Robert Nideffer, Zach Layton, and Ezra Teboul offered incisive commentary along the way. I am particularly thankful to the individuals who gave their time for interviews; the full list is provided in Appendix A.

1 An Episode of Light: Canada from 1967 to 1992

This book offers an account of the conjuncture of media technology, innovation policy, and creative art practice that emerged and flowered in Canada from the late 1960s to the early 1990s. Aligning roughly with the chronology of the installation and first mass adoption of digital media and computation in Canada, this is a story of glittering innovations in new media, as well as squandered opportunities and unrealized futures that came into view during these years. Taken together, the cases around which the book is organized highlight the decisive, catalytic role played by artists in what appears today as a sustained *episode of light*,¹ a period of intense creativity in the arts and media technology in Canada that can be dated from 1967 to about 1992. Out of this conjuncture also emerged new art forms, interdisciplinary configurations, prescient speculative designs, and novel institutional and policy frameworks, all of which were marked by a remarkably sustained and reflexive deliberation on the relationships between humans and their extensions through media.² This was a period in which media innovation became tightly enmeshed in a critical reimagining of a uniquely Canadian nationalism, during which Canada achieved a kind of distinction internationally, not only in what is acknowledged to be an influential Canadian “discourse on culture and technology,”³ but in a set of creative practices in both domains that emphasized sensorial immediacy, embodied interaction, and improvisational expression. These values comprised a shared culture, or what I will term an “alternative technological ethos”: a common way of apprehending technology as a malleable material, open to revision by artists in use, and subject to both conceptual and functional reimaginings.⁴ It is toward a clearer understanding of this alternative technological ethos—its historical and political-economic contexts,

its defining qualities and practices, its achievements and failures, and the lessons it might offer—that this book aspires.

This “episode of light” begins with the heady, even ecstatic enthusiasms of the World Exposition at Montréal, which marked the nation’s centenary in 1967. It spans the following quarter-century, as new technologies for computing and networking begin to seep slowly into laboratories and studios, spreading with increasing rapidity across the country. The period it describes corresponds closely with the build-up or installation phase of what will here be called the “Information Paradigm”—a shorthand to indicate not just the technological underpinnings of computers, software, and networks, but also the artistic expressions that worked within or challenged the limitations of these developing infrastructures as cultural terrains.

Canada had a well-established set of institutions and technocultural discourses already in place as the installation phase of the Information Paradigm was getting started. Public policies supported cultural and scientific institutions, such as the National Research Council and the National Film Board, that were open to interdisciplinary experimentation. Within the federal government, the connections between cultural and communications policy were recognized, if not coherently worked out, when they were placed under a single government department for a brief fifteen-year period. New university-based interdisciplinary academic programs (like Simon Fraser University’s Faculty of Interdisciplinary Studies), departments receptive to artistic research directions (like the Computer Science Department at the University of Toronto), and art schools with both traditional and experimental wings (like the Ontario College of Art and the Banff Centre in Alberta) were able to harbor, incubate, and endorse new approaches, often also assuming the role of official advocate, articulating a coherent rationale for recognizing artists as valued actors in techno-aesthetic innovation. Independent, artist-led initiatives were also fostered, enabling the formation of a publicly funded national network of alternative centers, many of them organized around cooperative exploration of both older communication media and the emerging digital technologies. These preexisting policy and institutional frameworks were themselves part of a long and widely remarked-upon history of the coevolution of communication and nationalism in Canada.⁵ This intersecting history of media and national consciousness also contributes to the intensity of the book’s starting point in 1967, when the nation was experiencing a palpable political reinvention

alongside its centennial celebration, and artists were taking on the slippery challenge of defining what it might mean to speak of a distinctly Canadian culture.

In the 1970s and 1980s, the installation phase of the Information Paradigm began to accelerate and its potential threats and opportunities came more sharply into view. Against this backdrop, there arose among some Canadian artists a newfound clarity in their efforts to analyze and critically intervene in what were already beginning to be recognized as potentially restrictive standardizations, as corporate consolidation over the information interfaces and applications spread during the last decades of the century. Scattered throughout this book are cases that address some of these critical interventions, in which artists issued challenges to and proposed solutions for a wide range of problems: the design of humane soundscapes, the “transparency” of user interfaces, the configuration of creative practices in application software, the nature of global interactive networks, and the place of the human body in the emerging field of virtual reality, to name a few. These interventions were in part fueled intellectually by the homegrown Canadian discourses on technology and culture, typified but by no means limited to Marshall McLuhan’s ideas, which privileged artistic insights as a creative and critical resource for understanding the deeper and profoundly ambivalent long-term effects of new media.

With the advent of the personal computer in the 1980s and the World Wide Web in the early 1990s, what I will call the installation phase of the Information Paradigm comes to an end and its mass deployment phase begins in earnest. It is at this historical juncture—the dawn of the internet age, around 1992—that this book comes to a close. The deployment phase of this cluster of enabling technologies coincided, paradoxically, with the cooling of Canada’s burst of self-confidence as a modern nation, when a host of existential crises within its own borders, and the rampant pressures of a neoliberal international order beyond them, ushered in a new era.

At the political level, Canada in the later 1980s was consumed by the challenges to national unity occasioned by a rising Québec independence movement, and by the perceived threats to economic autonomy and national treatment of cultural funding arising out of the negotiations for free trade with the United States after 1984. The country descended from an apogee moment of exuberance and national self-discovery in 1967 to existential crisis and doubts about its very viability as a nation. This declining domestic

arc occurred alongside the hastening *rise* in adoption of digital technologies at large, building by the early 1990s toward the transnational corporate-led surge into digital media convergence and deregulation. The resonant energy unleashed through the intersection of Canadian cultural self-refashioning and experimental media practices was attenuated just as the information deluge of the 1990s swept over the planet, bringing to Canada (as everywhere else) a corporatized version of digital culture. It was within the maelstrom of this “globalized” techno-environment that digital media innovation itself became a deliberate object of research policy in Canada, though a confused one with frayed connections to the kinds of open-ended, improvisatory cultural practices that had come before. This disjuncture at the official level between research and cultural policy occurred while rising consciousness of indigenous histories and cultural diversities was further undermining any lingering credence in a unitary pan-Canadian identity defined in terms of advanced media technologies.⁶

In summary, the flowering after 1967 of a media-inflected national consciousness in Canada coincided with the transitional years into the Information Paradigm. *Northern Sparks* contributes to national studies of innovation systems by offering a detailed historical account of the epochal transition to digital culture in Canada, emphasizing the significance of the creative arts to technological development, as well as to broader conceptual understandings of new media innovation at large. Set against our present moment, rife with denunciations of unbridled innovation in the information industries, the consideration here of the experimental arts as both a beneficiary *and* driver of technological invention takes a different tack. Conceiving artistic creation as endogenous, rather than external, to the sources of technological innovation can provide a more complex and nuanced alternative to dominant, narrowly market-based definitions of innovation, on the one hand, and simplistic calls for the vaguely imagined “integration” of arts and technoscience, on the other. Rather, in the history offered here, arts-animated innovation in media technology is grounded in specific material practices centered around human expressiveness and sensorial immediacy that were by turns nurtured, focused, and critically reoriented across a variety of sites for collaborative knowing and making.

Within the confluence of the twinned historical forces that shape this history—a national-political reinvention and a shifting technological

paradigm—Canada’s alternative technological ethos thrived across the spectrum of the creative arts and sparked *multifaceted* innovation outcomes: artistic, technological, scientific, and conceptual. This “alternative” attitude toward technology is distinctive in the sense that it allows for multiple ways of making and knowing, judging and valuing to be in play at once. Innovation, as David Stark has argued, emerges from the sustained influence of multiple and even potentially “dissonant” alternatives. Considered in this way, innovation is the creative practice of recognizing and bringing to fruition the friction that results as these alternatives clash or converge.⁷ Understanding a technology as a malleable material for artistic exploration is valuable particularly when the technology is itself in an indeterminate state, not yet stabilized or even recognizable as a category. The improvisatory immediacy, direct interaction, and sensorial richness that characterize the techno-creative practices of this period in Canada are relevant beyond their context precisely because of how they can help us discover, through exploratory use, the possible forms of an indeterminate technology or media environment. Insofar as the affordances of a new tool, technology, or medium are not known in advance, they remain untethered from any particular function, end, or utility. But, after a new tool or system or interface is instantiated, made concrete in a first creative instance, it can be quickly normalized, assuming an assignable instrumental purpose that then appears inevitable and essential to the technology itself.

The central claim of this book is that the alternative technological ethos in Canada was distinctive in the variety of ways it was able to shape and value new media technologies through experimental artistic uses. This variety generated innovative outcomes that went beyond the actual artworks produced, or even the stabilization of aims or requirements into valuable tools or systems that often grew from the creative process. The innovations were also conceptual and philosophical—alternative ways to think about and approach interactive computing, sound environments, networked experience, and immersive environments.

These explorations and discoveries occurred across the full spectrum of the arts. Responding to this multiplicity of forms, the book’s narrative structure is organized as a systematic, though not always neatly chronological, examination of the variegated ways in which this alternative technological ethos was germinal in each medium or art form. Imagined in terms of sensorial

modalities, the story proceeds from moving images to graphical and kinesthetic interaction, then to sound and music, networks, and immersive environments. The alternative technological ethos played out at a variety of scales and organizational forms, from independent artists working in studio labs to formally mandated projects in publicly funded research and cultural institutions. It begins with the methods and influence of a singular artist, Norman McLaren, who, working alone or in small teams within the National Film Board, devised a host of original film animation techniques for acclaimed experimental works that were also subsequently legible across several fields as “proto-computational” (chapter 2). In chapter 3, two separate professional and institutional perspectives come together around a single short-term artistic production by the NFB and National Research Council, which generated artistic and technological outcomes that could, in turn, be exploited in different social and economic worlds: animation production, human-computer interaction, software engineering. Chapter 4, on gesture and interactivity, rediscovers the alternative technological ethos in small teams working both within major research labs and in small studio labs. Across the five examples highlighted in this chapter, the computer itself began to be considered as a more or less capable agent. This profoundly novel recognition itself generated the common challenge of finding ways to preserve sensorial immediacy across the threshold of human-computer interaction, both as creative practice and interdisciplinary science. Chapter 5 shows how the alternative technological ethos played out in different ways within the sonic realm, profiling the performers and composers who expanded music practice through improvisatory interactivity and intermediality, and brought to life new musically inspired interdisciplinary fields, like acoustic ecology and sound art. In chapter 6, this alternative ethos is shown in a comparison of two contrasting examples of creative practitioners discovering new uses of interactive networking, the first in a series of projects initiated by independent artists, and the second involving Telidon, an ill-fated government-initiated videotext system. The final case explores how virtual reality was contested as a new artistic medium and focuses on the attempt at the Banff Centre to discover new uses for, and formulate critical analyses of, immersive visual and sonic environments.

Another main claim of this book is that the alternative ethos was resonant with and therefore amplified by its being situated within the pair of intersecting historical arcs that etch out the background of the period: the

national-political and the technological-mediatic. As any formative technological era transitions toward maturity, the openness to alternative modes of making and valuing is reduced.⁸ With the mass adoption of standardized information interfaces, protocols, and packaged software applications accelerating rapidly from around the mid-1980s, a definite technocultural closure was occurring just as, at the political level of Canadian arts and communication policy formation, the wider social impacts of these various kinds of standardization were becoming more difficult to discern, understand, and develop appropriate policies to address.⁹ Not surprisingly, by the mid-1990s, Canada's capacity to come up with policies integrating arts, technology, and innovation actually diminished just when its unique experimental histories in this arena might have helped provide a homegrown alternative to the apparent inevitability of transnational corporate media convergence and the commodification of digital media during the dot-com boom years.

From Apogee to Crisis: Canadian Arts and Technology Policy

The period from the mid-sixties to the mid-eighties will be seen by Canadian historians as the period of one of the most radical reinventions in the history of a country, from Expo 67 to the Charter of Rights and Freedoms. We reinvented ourselves as a multicultural bilingual nation. We had to go through a near-death experience, but we did reinvent ourselves.¹⁰

Michael Ignatieff, a Canadian public intellectual and erstwhile Liberal politician, is hardly alone in thus associating the beginning of this radical reinvention with the moment of its symbolic apogee: the world's fair at Montréal celebrating "Man and his World." The fair welcomed the world to Canada with verve and sophistication, most famously setting off a powerful affective charge to the throngs of attendees through its extensive use of immersive audiovisual and multimedia environments.¹¹ For literary scholar Donald Theall, writing at the time of Expo 67, world expositions always produce symbols of the future, and this symbol was of the "total environment" in which the juxtaposition of information from many sources—like the fair's many pavilions with multiscreen displays—elicited a visceral awareness of a "new sense of space." This new kind of media environment not only juxtaposed myriad "particles of experience" in satisfying ways, but assisted visitors to gain a wider "awareness of society as a whole," one that was "deeper

and more comprehensive.”¹² In short, the modern reinvention of Canada was catalyzed by a global event that ushered in the technological imaginary of the information age.

More recently, historians, film scholars, and exhibition curators have drawn out a more mixed set of messages about the exposition that go beyond its architectural landmarks and the multisensorial allures of its plethora of media displays. Architectural historian Indirbir Singh Riar points out that while Expo 67 played a crucial role in shaping Canada’s “collective sense of cultural representation and global belonging,” it also contained glimpses of doubt about the plausibility of any simple “abiding faith in techno-scientific salvation” in the “aftermath of global war and the terror of nuclear holocaust.”¹³ This ambivalence is spotlighted by Riar in several key pavilions that get less attention than the most famous ones, such as Buckminster Fuller’s geodesic-domed US pavilion, or the various pavilions hosting multiscreen movies. A pavilion dedicated to First Nations history and culture was widely acknowledged for presenting a hard-hitting denunciation, for the first time at a national scale, of the suffering and exploitation of Aboriginal inhabitants of Canada.¹⁴ Another critical perspective is seen in the pavilion “Man the Producer,” which asked visitors whether they thought technology offers you “material riches or faceless conformity,” or whether technology permits you “to listen to the universe or prevents you from hearing yourself.”¹⁵ Such nuance has its roots in the relatively wide intellectual input sought by Expo 67 planners from a range of Canadian scholars and artists, and is closer in fact to the actual positions held by McLuhan on the mixed effects of new media than is widely supposed.

Commenting from Expo 67 during the first five-continent satellite TV broadcast, *Our World*, McLuhan summarized how he understood the artist as a sensory repository of insight into rapid social and technological change.

People have always been terrified of the present. The only people with enough gumption or nerve to look right at what’s happening under their noses are artists. They’re specialists in sensory life. They just deliberately look at the present as if they dared it to ruin them, like Perseus and the Gorgon. The artist looks into the mirror of art and says, the heck with the Gorgon’s image, I’m not terrified. Most people expect, when they look at the present, to be turned into stone, as by the Gorgon. They are terrified, and therefore they prefer the rear-view mirror. Everyone who looks ahead, as it were, is in effect looking in the rear-view mirror.¹⁶

Just as some historians look now at Expo 67 with a more nuanced view of its many marvels, so too has the iconic year 1967 received more measured reassessments. Doug Saunders, writing in 2017 for the *Globe and Mail*, argues that 1967 is indeed “the hinge upon which modern Canadian history turns and, in certain respects, the key to understanding the challenges of the next half-century.” But for Saunders, the year is better seen as a marking point when a number of sea-changes that had already been under way for decades surfaced officially, on matters ranging from women’s and gay rights to aboriginal recognition and ethnic and cultural identity:

Canada was not remade by the decisions of 1967; it was reflected by them, for the first time. What began in 1967 was official Canada beginning to catch up with the real Canada. And that is also the lesson to be carried forward to 2017: Canadians tend to be ahead of their institutions, and every few decades it is time for a dramatic catching up, like the explosion of adjustment we saw in '67.¹⁷

Much of the cultural infrastructure that was fundamental for the developments covered in this book had already been set in place during the several decades before Canada’s breakout year. Canada’s two flagship federal cultural agencies had been established before World War II and remained fundamentally unaltered under the urbane, intellectually sophisticated Prime Minister Pierre Elliott Trudeau, who led the country between 1968 and 1984, except for a short interregnum in 1979–1980. The National Film Board (NFB), established with a mandate to interpret Canada and Canadians to the world, and the Canadian Broadcasting Corporation, tasked with ensuring Canadian voices would be heard against the onslaught of US commercial radio, were both humming with innovation decades before the Trudeau years.

A 1949 blue-ribbon study, the Massey-Lévesque report, had provided a blueprint for developing arts, humanities, and social science research funding, with many recommendations for government actions and policies, including the founding of the Canada Council (effected in 1957). The Massey-Lévesque report, known officially as the Report of the Royal Commission on National Development in the Arts, Letters and Sciences, should be read, according to cultural theorist Jody Berland, as opposing the specific threats of US domination over Canada in areas like broadcasting, publishing, and scholarship, but at the same time as welcoming “internationalist” modernism in the fine arts.¹⁸ As much as this preferential treatment of “high art” over “mass culture” infuriated some commentators (including McLuhan), the effect of the

Massey-Lévesque report was marked and comprehensive, as summarized by Tom Henighan:

Perhaps the most amazing thing about the Massey-Lévesque Commission is that its recommendations, resulting in government actions and policies of many kinds, appear to have done the job. During the sixties, seventies, eighties, Canadian culture came to life. There were many reasons for this flowering—economic prosperity, increasing urbanization, and population diversity among them—but the establishment of the Canada Council, the commitment of government funding to the arts, was probably the single most important factor in effecting this change and in sustaining it. The growth of Canadian arts and culture during this period was amazing; even more amazing, perhaps, was the Canadian public's acceptance of this growth.¹⁹

Under Trudeau's first government (1968–1972), employment programs supported “Local Initiatives” driven by grassroots community needs, and “Opportunities for Youth” designated formally under cabinet mandates to promote “participation,” “culture,” and “engagement.”²⁰ The bureaucrat recruited by Trudeau to direct these programs, Bernard Ostry, summarized the rationale as one of developing and strengthening “a sense of Canadian citizenship, chiefly through programs that would aid participation and assuage feelings of social injustice.”²¹ Before being shut down under charges of scandal, subversion, and mismanagement, these jobs-related programs contributed the initial funding for what would become the national network of artist-directed centers, a vital component of Canada's media innovation culture in the 1980s and beyond.²²

In 1969, Trudeau also established a new federal Department of Communications with a broad mandate that would only grow over the next decade. Initially dealing mainly with the science and engineering aspects of the field, by the late 1970s the Department of Communications had expanded its scope to include portfolios supporting arts and culture, which until then had been located in the Department of the Secretary of State. This attempt at merging culture and communications, content and carrier, or software and hardware, did not endure after 1993, when the Conservative government of Kim Campbell reverted to a reactionary view of the cultural portfolios as the repositories and custodians of national heritage and identity, while the technological components were shuffled to a revamped Industry ministry incorporating science funding and policy as well.

In its initial years, however, the Department of Communications spearheaded another national study, known as the Telecommission, that came

out with its own report under the title *Instant World (Sans Frontières)*. Though lacking the immediate effect of Massey-Lévesque, this report had a farsighted understanding of what would become known as “media convergence” two decades later:

Think of a system incorporating computing, publishing, newspaper, broadcasting and library, telephone and postal services of the country, together with large slices of teaching, of operations and of many professional activities. All these each growing in its own right and subsumed in one system will outstrip in magnitude and importance any industry in which human beings have been previously engaged.²³

Instant World also took the temperature of the intellectual and artistic community in Canada, including a chapter on the effects of new media technology on the arts and letters. This chapter, on the “Soul in the System,” was the result of coast-to-coast hearings and reflected a solid dose of skepticism on the part of the artists and intellectuals consulted. Jacques Godbout, a film director from Québec, summed up this skepticism acerbically when he remarked: “The intoxication that takes hold of managers is in fact due to the fabulous quantity of knowledge which they would like to concentrate, conserve, and disseminate rationally so as to ensure that it will perpetuate the economic-technological dictatorship that provides them with a living.”²⁴

The report compared Godbout and others to cultural Luddites, and the tone of the chapter overall reflects something of the dichotomous view of these matters propounded by C. P. Snow in the much discussed “two cultures” debates after 1959.²⁵ Notwithstanding this tendency to pigeonhole humanists as “anti-technological,” *Instant World* was forward-thinking on another score. The “information superhighways” envisioned, *avant la lettre*, would not just be used for broadcasting messages to the population at large, but would enable individuals to express themselves in new—albeit largely unspecified—ways. For McGill University communication scholar Marc Raboy, the report was at its most prescient when it proposed for the first time the concept of communication itself as a “human right.” Anticipating a world of bidirectional communication flows, and of “user-generated content” (to use a later jargon), *Instant World* offers a tantalizing glimpse into the mindset of Trudeau-era cultural technocrats forecasting what it might mean for public policy to support such an activated, communications-rich media culture.²⁶

The report's impact was muted. According to Pierre Juneau, one of the cultural mandarins recruited by Trudeau to modernize Canadian arts and communication policy,²⁷ the *Instant World* report helped start a federal-provincial battle over control of communications. Juneau, in an interview with the author, remarks that the Telecommission had not really dealt with the fundamental problem of that time; namely, how to ensure that there would be as much public investment in content as in hardware. "It was the start of the hardware mania," Juneau recalls, and this insight led him to convince Trudeau to put the Department of Communications and the Secretary of State together—to bridge hardware (technology, and its regulation) with "software" (cultural content) in one government department.²⁸

By the time the Department of Communications had fully integrated the cultural and technology portfolios in 1979, Trudeau was briefly out of office, and pressure was building toward the first of two referendums on Québec independence (held in 1980 and 1995). The existential crisis over national unity, referred to by Ignatieff above, would become the first of two great battles won by Trudeau in the latter years of his political career. This first battle, about whether to keep Québec in Canada at all, elicited a tremendous upsurge of cultural energy as well as political activism in that province during the 1980s, which can only be touched on in this book (see chapter 5 for musical aspects arising in the context of the separatist movement). The second of Trudeau's battles, over the repatriation of Canada's Constitution from Great Britain in 1982, established a national Charter of Rights and Freedoms. It is worth recalling that Trudeau, a constitutional law professor before he entered politics in 1965, was a charismatic figure who operated at a mythic level insofar as he was able to serve as a lightning rod for diverse energies. In political terms, this was typically expressed as a vision of Canada as an open society, an original experiment that was neither American, British, nor European.²⁹ This openness to the world, however, was itself controversial, since the funding of Canadian "content" as such was becoming an ever more complex matter as the consideration of culture became increasingly approached as a matter of industrial policy.

A signal of the turn toward a new discourse of the "cultural industries" (later elaborated in Blair's New Labour government in Britain as "creative industries")³⁰ can be located in yet another large-scale Canadian effort at national consultation in the arts, this time led by Louis Applebaum and Jacques Hébert. The Report of the Federal Cultural Policy Review Committee,

overseen by Applebaum and Hébert and published in 1982, showed acute awareness of the need to bolster the content *industries* (print, television, film, sound recording) against primarily American imports, while at the same time fostering “excellence” in the fine arts as such. What is most salient in this context is the report’s decidedly constricted view of the relationship of art and technology. Arguing that the NFB mission should change to take on a more limited responsibility for “research and development” in the “art and science” of film production, the Applebaum-Hébert Report *also* briefly discussed the idea that the Department of Communications itself should have its own “art and technology” program. The objectives of such a program would have been the “promotion and funding of research and experimentation, and the provision of access to research results and the hardware itself to artists across the country.”³¹ Though this idea was not even included in the Report’s actual recommendations, the Department nonetheless began to support some aspects of computerization within arts organizations, though not specifically formulated as creative research.³² Partly in response to this rising interest inside the federal department to which it formally reported, and partly in response to what its founding director called a rising international “technological arms race” for preeminence in digital media, the Canada Council would in turn shortly start its own funding program for Media Arts, including “computer integrated media”—among the first of its kind.³³

Canada soon faced radically increased continentalist economic pressures following Trudeau’s retirement and the 1984 election of a Conservative government. National unity remained an open sore, since Trudeau’s constitutional legerdemain had failed to accommodate Québec’s aspirations, and the two growing tensions—over national unity, and over free trade with the United States—took much of the nation’s attention from the mid-1980s onward. Much of the cultural community was preoccupied with a nationalist agenda to preserve the support infrastructures that had been built up in the half-century since the CBC was established in the height of the Great Depression. Yet another policy paper from the Department of Communications in 1987 recognized the rising economic importance of software as an industrial component and the need for Canada to develop its computer and information industries for purposes of national competitiveness.³⁴ But, according to University of Montréal communication scholar James Taylor, nowhere in this report—issued from the same Department of Communications whose founding came out of an attempt to merge the concerns of

content and technology—was there a clear recognition of the vital importance of research on the interaction of technology and users themselves:

The [Department] has traditionally straddled the domains of economic policy (through research, telecommunications, new technology development) and of social policy (through broadcasting and culture). This division—so reminiscent of Snow's two cultures—has tended to support a stereotype: that technology is profitable, but only secondarily social (in that one must do a "needs" analysis, and something about "impact"), while culture is social but unprofitable. What now confronts the Department is the realization that technology without sociability is not profitable: it doesn't even work. To judge from the paper that has been issued, it would seem that the problems of people still come out as an inconvenient side-effect of technological change, rather than the only way to benefit from it.³⁵

By 1993, the Department of Communications was dissolved, shunting culture into the pigeonhole of national heritage and technology into that of industry and science. This end of the "under one roof" attempt at policy coordination should not be considered a failure outright, but rather as an unrealized opportunity. Overall, this is hardly surprising, given the complexity of mounting challenges of the period. An explicitly formulated "innovation policy" integrating the creative arts with scientific research and technological development was never articulated, though the intellectual ingredients that could have shaped one can clearly be discerned from the present historical vantage.

Media Arts in Innovation Policy

In order to associate the creative arts with "innovation," it is first necessary to pry the term away from its commonplace use as a business nostrum—a remedy to cure all ills. Walter Isaacson's best-selling 2014 history of the digital revolution, *The Innovators*, argues that its next phase can come only in a "true fusion" between technology and the "creative industries."³⁶ Educators seek to make science, technology, engineering, and mathematics more attractive by adding in the "arts," like some special sauce, to broaden technical education from "STEM to STEAM." The US National Academy of Sciences published a 2003 report, which I contributed to, urging the technology community to go "beyond productivity" by considering the role of the arts and design—here termed "creative practices"—as foundational inputs to the tech industry and university research, rather than just decorative

afterthoughts.³⁷ In the general spirit of these well-intentioned, but not very specific, prescriptions, this book advances a historically grounded case for repositioning artistic experimentation within innovation policy studies. This section first reassesses the concept of sweeping epochal, or paradigmatic, waves of innovation in terms of the multitudinous temporalities of influence at work in the creative arts. Next it considers how the Canadian case studies of this book, which document an alternative technological ethos for research-based creative practices, may be viewed in relation to the concept of national innovation systems.

In the innovation policy literature,³⁸ the so-called “technological revolution” clustered around computing, software, and networks is but one in a recurrent pattern of innovation waves dating back to the first industrial revolution in England during the eighteenth century. Austrian-American economist Joseph Schumpeter developed the concept of “long waves” as recurrent patterns of industrial innovation that take the shape of a logistic curve of buildup (installation), widespread diffusion (deployment), followed by saturation and replacement as another breakthrough of invention gives rise to a new long wave.³⁹ The cases examined in this book took place during the buildup or installation phase of what Manuel Castells identifies as the fifth of these long waves, centered in new information and telecommunication technologies.⁴⁰ This installation period began with the earliest computers in the 1950s and 1960s, moving successively in the 1970s and 1980s toward exponential miniaturization, faster processing speeds, more user-friendly applications and interfaces, and a broader palette of audiovisual capability.

In an influential study of what was then called “Mode-2” or transdisciplinary research, published in 1994, Michael Gibbons and a group of coauthors considered the arts and humanities as outsiders to the production of new technoscientific knowledge, “standing aside as quizzical commentators who offer doom-laden prophecies or playful critiques, and as performers provide pastiche entertainment or heritage culture as a diversion from threatening complexity and volatility.”⁴¹ Gibbons also observes the way artists are implicated in the culture industry as image makers, but makes no reference to the artist as an innovative actor per se. As further observed by neo-Schumpeterian economist Christopher Freeman, artistic and cultural components of techno-economic paradigm changes have “a logic and time of their own. They may anticipate the future or recall a nostalgic vision of the past.” In Freeman’s history of industrial revolutions,

new technologies are seen broadly to act on the “tides of cultural production,” but the arts are not considered to play even an indirect role in shaping new technologies.⁴² While it is true that in earlier periods, experimental artists actively took up photography, cinema, and television only after they had been established industrially, the same is not the case in digital culture. This book presents a host of cases of early adoption and co-invention by artists of digital technologies as such, but also of the creation of novel *kinds* of objects: fresh interdisciplinary configurations, like acoustic ecology and human-computer interaction; new creative genres, like soundscape composition or interactive installation art; and approaches to tool building by artists, in fields ranging from animation to music composition and interaction design.⁴³ A more concretely grounded and complex picture emerges, therefore, than that of futuristic anticipation or nostalgic recollection. In innovation policy terms, it will be important to track and understand transitions and overlaps, retrievals and repurposings, between different historical periods and artistic traditions as much as the ruptures and breaks.⁴⁴

The alternative technological ethos documented in this book favored the sensorial immediacy of artistic practice as a method of exploring the emerging properties of electronic and digital technologies. The interplay of improvisatory or performative practices in film, music, or dance, on the one hand, and the formal or procedural logics of programmable systems, on the other, was generative in advancing original, human-centered understandings of the rising technologies of the fifth innovation wave. This interplay between tacit and explicit forms of knowledge played out differently in the various arts with their separate histories; musical composition and performance, for instance, have a set of notational practices enabling formalization, which differs from other performative practices like dance, and from narrative or pictorial art forms. The details of these differential affordances for leveraging the formal and procedural logics of computation are provided in the chapters to come; for present purposes it is well to note that the differentiation between the arts with respect to improvisatory immediacy and discrete formalization is akin to the concept of diverse “epistemic cultures” which emerged from laboratory studies in the sociology and anthropology of science.⁴⁵ Karin Knorr-Cetina’s concept of an epistemic culture emerged from detailed analysis of work practices, and in particular the multiplicity and contingency of *inscriptions* that are used to record, stabilize, and communicate new scientific knowledge.

In a 1999 essay collection, *Picturing Science, Producing Art*, Caroline Jones and Peter Galison, argued for moving beyond the “focus on ‘art’ and ‘science’ as discrete *products*,” to look at “commonalties in the practices that produce them.”⁴⁶ In their subsequent efforts to realize this agenda, Galison’s and Jones’s work has sought to establish commonalties between twentieth-century visual art studios and experimental physics labs, emphasizing the similarities in architectural and spatial properties as well as the material and symbolic practices of the artists and scientists inhabiting them.⁴⁷ Focusing similarly on the links between institutional conditions and the specific practices afforded within them, my own research has tracked the increasingly dense formation of *hybrid* studio laboratories over the twentieth century, a tendency which accelerated during the several decades that saw the incorporation of the computer into arts practices, and into cultural applications more broadly.⁴⁸

Canada lacked the corporate research behemoths of the United States, like ATT’s Bell Labs or IBM, or the geographic concentrations of academic-industrial-military synergy like Boston’s Route 128 or Silicon Valley. But it did have its own well-established national cultural and institutional infrastructure, parts of which were well-disposed to creative research in communications media, and a spate of new academic institutions with interdisciplinary missions established in the post-Baby Boom era. During the same period, France showed a marked centralized *dirigiste* approach, as has been well documented by Georgina Born in her detailed ethnography of the “rationalization” of contemporary music at IRCAM.⁴⁹ The UK, by contrast, tended primarily to locate the centers for early computer arts experiment in the polytechnic institutes, rather than in the universities, elite art schools, or music academies, reflecting a more rigid social structure and inflexible institutional ecology than Canada enjoyed.⁵⁰ Canadian cultural institutions and policies may have benefited from developing within a nation that was, to adopt a phrase from McLuhan, the “borderline case,” benefiting from a close proximity to the United States and from its former imperial ties to England and France in a way that facilitated extensive knowledge flows of people, ideas, and technologies, while maintaining a certain critical distance and ambivalence about these influences. In this view, Canadian culture turned its marginality to productive use as a creative resource.⁵¹

In comparative studies of national innovation systems, interactive learning processes, which emphasize knowing by doing, have been put forward

as alternatives to a dominant linear model of innovation that specifies a stepped sequence from science to technology to development to innovation diffusion.⁵² This book does tell a specifically Canadian story of how arts-focused media innovation was fostered within a unique national cultural and research infrastructure, and it also gives rich empirical evidence of how interactive learning between different actors—artists, designers, users, and researchers—can also lead to multidimensional, not just singly acknowledged outcomes. One of these dimensions is concerned with ethical and conceptual aspects of an emerging technological *imaginary* while it is still in a formative, preparadigmatic stage. The works of many of the Canadian artists profiled in this book can be usefully viewed in this premonitory sense, that of generating advance knowledge through the creation of artworks or systems that goes beyond their workings as technological objects as such or their aesthetic value.⁵³ For scholars and practitioners today concerned with reassessing the recklessness of disruptive innovation,⁵⁴ it is salutary to note that this kind of criticality combined with invention was often embedded within the actual creation and research practices of artists working during the earliest, formative period of digital media in Canada.

As “research-creation” becomes an ever more recognized watchword in higher education programs and funding schemes,⁵⁵ research policy can well stand to be better aware of closely documented historical cases that can serve as clear models and cautionary warnings. The book’s central argument, that Canada’s alternative technological ethos encompassed multiple ways of knowing, making, and valuing across the arts and technology, leading to multidimensional innovative outcomes, is put forward to help inform this kind of historically grounded policy formulation.

Northern Sparks

The cases in this book range broadly, both in terms of the arts and media practices covered, and in terms of the analytic resources needed to explain them. Whereas media art history has lately sought to become a platform for multiple media perspectives,⁵⁶ in practice most studies tend to bifurcate along conventional disciplinary lines between the visual and sonic realms.⁵⁷ This study, by contrast, spans film animation, music, the emergence of sound art and acoustic ecology, cybernetic cinema, interactive installation

art, virtual reality, telecommunications art, software applications, and the branches reaching out from all of these creative practices to the emergent metadiscipline of human-computer interaction (HCI). To address such a breadth of practices, methodological approaches from several fields need to be enlisted, drawn in particular from the liminal space between the already interdisciplinary fields of media art history, and of innovation within science and technology policy studies. While some readers might find the level of close reading in some of these chapters too granular, others will no doubt lean in the opposite direction and want greater precision in my technical or artistic analysis. I have tried to strike the tricky balance found in the best sociologically oriented cultural criticism, of understanding “the works themselves” without losing sight of their historical and social contexts.⁵⁸

This book is also informed by my own direct involvement in the media art and technology field in Canada. Between 1980 and 1993 I was employed at the Banff Centre for the Arts, where I was the founding director of its media arts division. From 1993 to 1997 I worked as a program manager for a Montréal-based federal research center for information technology innovation, founding a new program for “networked cultural information systems.” In those same years, I also served as consulting policy analyst for new media at the Department of Canadian Heritage, within the directorate for arts policy.

My government service occurred immediately after the dissolution of the Department of Communications, which had since 1979 combined responsibilities for communication policy and research with arts and cultural development. Several overlapping policy exercises were going on at once, with chaos and bureaucratic infighting being par for the course. I often shuttled physically, as well as conceptually, between Heritage and Industry, trying to bring my practice-informed knowledge from the field to bear on the formulation of policy by the Information Highway Advisory Council, jobs-focused measures for new media training, and designing programs to support collaborative research between disciplines, arts centers, and research labs. This vantage point gave me a privileged view into the curious and often frustrating instability and incoherence Canada was experiencing during those years. As Marc Raboy and other scholars have documented,⁵⁹ when culture and communications policy in Canada was subjected to new globalizing pressures, important national histories were often overlooked or, at best, distorted. My own advocacy and analysis work

for the Canadian government instigated exploratory research into some of the cases that are finally being published in this book.

The impetus for this book initially grew out of this experience as an active proponent of the arts in Canadian new media research, and therefore the methods employed in telling this history are in part ethnographic. Through my personal contacts, I was able to identify and interview many of the key figures in the cases studies, but in some instances, I also had direct knowledge as participant in or instigator of projects and initiatives that occurred within the time frame of the study. The interviews I carried out took the form of open-ended conversations, with individuals I selected as a researcher with an “inside observer” point of view. The names and dates of individual interviews are provided in Appendix A.

Chapter Summaries

This book begins with antecedents to and the deployment of some of the earliest applications of computing to filmmaking. Chapter 2 foregrounds Norman McLaren’s work at the National Film Board, introducing an account of “proto-computationality” derived mainly from the procedural, notational, and quasi-algorithmic methods used in the films he produced from the late 1950s through the 1960s, mainly made with his closest collaborator at the NFB, Evelyn Lambart. McLaren’s artisanal methods at the NFB are presented in detail, and they are shown to have exerted a powerful influence on the emerging computer culture in North America because of the way they illuminated the creative potential of computer graphics. The National Film Board as an innovative techno-artistic center is contrasted to the forces shaping the institutional development of computer graphics in the United States.

Chapter 3 presents a case of the co-development of art and technology via a sustained collaboration between the NFB and the National Research Council (NRC). In the mid-1960s, the NRC began a research program using interactive computing applied to “creative applications” in film animation and music composition. On commission from the NFB, the figure-based animation script of Peter Foldes’s film *Hunger* was realized computationally by a team of NRC scientists and engineers, using a custom-built animation system supporting real-time direct manipulation modes of interaction between artist and computer. The research programs of the two sponsoring institutions were complementary, and the roles of the engineers, artists,

producers, and programmers were fluidly defined and symbiotic. *Hunger* was the first computer animation to be nominated for an Academy Award (1974), and it won the grand prize for animation at the Cannes Film Festival. The chapter ends with an account of the later outcomes of this collaboration, beginning with a contentious incubation period when the NRC's system was used by young animators at the NFB. This usage contributed ultimately to the formation of one of Canada's early successful companies producing 3D animation software, Softimage, and the wider diffusion of the NRC-NFB nexus helped shape other successful business firms as well.

Chapter 4 presents a Canadian-oriented genealogy of artistically driven human-computer interaction, filling in some lacunae in the canonical histories of HCI, and pointing out the foreclosure of certain early potentials for interactivity in light of the standardization of graphical interfaces in personal computers in the later 1980s. The chapter begins by carrying forward the focus on animation from the previous two chapters and adding the results of research projects driven by applications in music, dance, and interactive installation art. The first example is a computer-mediated animation system using hand-drawn gestures first developed by Ron Baecker at the Massachusetts Institute of Technology's Lincoln Laboratory. Baecker carried this work forward in the 1970s at the University of Toronto's Department of Computer Science, which was early to support artistic exploration and development in both graphics and music. Joining Baecker at Toronto, musician Bill Buxton was influenced by the musical component of the same digital lab that had been used for computer animation at the National Research Council in Ottawa, as well as the previous analog electronic music instrument designs invented by Hugh Le Caine, also an NRC researcher, whose work since the 1940s anticipated the more widely known electronic synthesizers that appeared in the 1960s. Both of Buxton's prior influences emphasized the requirements of real-time performance and interaction at a time when these properties were in their infancy in computer music. Baecker and Buxton went on to become some of the leading figures in HCI as it emerged as a multidisciplinary field in the 1980s. Next the chapter considers Michael Snow's landscape film *La Région Centrale* (1971), which depicts a northern Québec landscape as seen through a custom-built mechanized camera eye. Importantly, the prescored program was replaced during the film's production by the artist's improvised gestures, but the programming concept was later implemented as a closed-circuit video installation (*De La*, 1971) at the

National Gallery of Canada. The codification of human gesture in dance is presented in an account of *Lifeforms*, the first widely used software application for computer-aided choreography, developed at Simon Fraser University in Vancouver by computer scientists and dancers, with input from and prominent application in the choreography of modern dance icon Merce Cunningham. The chapter closes with a consideration of Toronto media artist and programmer David Rokeby, whose *Very Nervous System* (1982–1991) uses a video tracking system that converts bodily movements into generative soundscapes. Alongside his landmark artistic advances, Rokeby was also an incisive critical theorist of configured interactivity, in writings that appeared just at the beginning of the euphoria about interactivity that spread rapidly with the mass diffusion of personal computers and the internet.

Chapter 5 pivots to performance, improvisation, and composition in music, which during these years in Canada enjoyed a remarkable surge in interdisciplinary energy and innovative outcomes. The chapter emphasizes the erosion of music's classical autonomy (initially formed in the nineteenth-century primacy of the romantic composer), the rising porosity of boundaries between music and other art forms, and the many interconnections drawn in Canada between music and other disciplines in the humanities, engineering, and social and natural sciences. This broader context is focused, first, through Glenn Gould's work as an author, which forecast a radical reconfiguration of the relationship between listener, composer, and performer, and also highlights his work as a creator of original radiophonic compositions that increasingly became the focus of his creative efforts after his retirement as a concert pianist. These original works blur the boundaries between music and language, documentary and fiction, and challenge listeners to expand their cognitive and perceptual capacities in ways that became formative for the future of sonic arts. The unique blend of free improvisation, sound experimentation, and popular folklore which comprises Québécois *musique actuelle* is highlighted in a discussion of various Canadian scenes for improvisational music, many drawing importantly on new audio and computer technologies. The alignment of the experimental energy of *musique actuelle* with the burgeoning nationalist forces within Québec society also occurred within an expanded aesthetic field blurring the formerly distinct boundaries separating music from other art forms. The chapter intensifies its focus on the Canadian contribution to the emancipation of music from its more calcified European classical moorings by recounting the origins and

development of soundscape studies and the interdisciplinary field of acoustic ecology. The chapter also considers the creative and legal challenges to the concept of music as intellectual property put forward by the Toronto composer John Oswald, through his microsample-based composition and his genre-defining theorization of "plunderphonics." It concludes with a close reading of several of Gould's lesser-known "contrapuntal radio" documentaries, demonstrating how their sonic layering techniques conveyed his ambivalence about technological modernity.

Chapter 6 presents two contrasting faces of cultural networking. It examines the main case of instructive failure in the book, an account of Telidon, Canada's pre-internet digital network, a financial fiasco of the first order despite the enormous funding and prestige accorded to the project by government and industry. Cultural input to the system was belated, if still formative to the growth of new media culture in Canada; Telidon's government lab developers designed the system around an authoring protocol for both text and graphics, which was driven more by data compression imperatives than by a concrete understanding of how users might engage imaginatively with the system. The Telidon example is set against the contrasting development of a Canadian network of artist-run centers, emphasizing experiments in computer networking and real-time video experimentation. Whereas the top-down, bureaucratically driven imperatives of Telidon were unsuccessful, the bottom-up artist-driven experiments using telecommunication and art helped to foster an informal experience of networking and collaboration across vast distances, well before the advent of the World Wide Web. Among the key works analyzed in this section are a 1974 multisite performance by Vera Frenkel, *String Games*, that made early use of video conferencing technology, and a set of communication-art projects and exhibits in which Canadian artists were the international instigators of networking as a new expressive medium.

Chapter 7 presents a case study of the infancy of virtual reality (VR), based on activities undertaken between 1989 and 1993 at the Banff Centre in Alberta. It focuses on VR as an emblematic technology, considered both as an opportunity and a threat, initially as investigated critically by a diverse group of philosophers, engineers, and artists who met at the Banff Centre for a 10-week residency in 1991 on the "Bioapparatus."⁶⁰ During this residency, artists Catherine Richards and Nell Tenhaaf teamed up with the Banff Centre programming staff to investigate VR as a technology freshly

open to artistic intervention, in order to take it beyond its initial scientific and military foundations, and to go beyond the quickly forming hype around the prospect of its widespread consumer adoption. At the core of the Bioapparatus construct is a notion of gendered embodiment in technology, and the chapter explores how the critical tenor of the residency elicited a rich techno-aesthetic controversy. The tensions inherent in the Bioapparatus residency were for the most part toned down in the next phase of the research program, the Art and Virtual Environments Project. This project attempted to envision various alternative futures for interactive immersive media environments by commissioning full productions of eight new artworks.⁶¹ This was the earliest large-scale investigation of virtual reality as an artistic medium, and its lessons are little remembered—but useful to recall—during more recent revivals of VR.

Chapter 8: the book ends with a short description of how the coming decades would unfold, as Canada entered the 1990s facing a complex conjuncture of political, cultural, and economic challenges. In contrast to the initial generative confluence of the arts, media technology, and national consciousness presented at the outset of the book, the last decade of the century found Canada's response to the explosive growth of information and communication technologies to be partially anachronistic, containing a sometimes paradoxical mixture of heady enthusiasm and inward-looking retrenchment. The Canadian alternative technological ethos, as both creative method and interdisciplinary model, nonetheless continues into the present day, with the emphasis in Canada on media interface and interaction, the interpenetration of art and research, and the artist as creator of "counterenvironments." The Information Paradigm, that is, the wave of digital innovation that built during the 1970s and 1980s, and burst into a flood after 1992, may now be taken for granted everywhere, but the coming waves of innovation, still inchoate and emergent, are in just as urgent need of creative and critical intervention. The Canadian story serves as an instructive object lesson today and for the future, across the range of its broad scope and manifold methods for mobilizing the arts, policy, and innovation.

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