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California Dreamin': Visioneering the Technological Future

First, inevitably, the idea, the fantasy, the fairy tale. Then, scientific calculation. Ultimately, fulfillment crowns the dream.

—Konstantin Tsiolkovsky, Russian space visionary, 1926[1]

By the end of the 1960s, many Americans—loudly and sometimes violently—challenged the trust society had placed in science and technology. Mounting ambivalence and pessimism about large technological systems and their effects on people and ecology forced debate about whether technology was an unalloyed force for good. Some Americans, for example, voiced concerns about the mortal dangers of the escalating arms race while others worried about an increasingly polluted environment or questioned a society that prized conformity, consumerism, and planned obsolescence. When asked about the biggest challenges NASA faced as the Apollo program ended, James C. Fletcher, the agency's head, pointed to the "anti-technology kick" the United States seemed to be on.[2]

Popular culture from the era reflects a mistrust of technology. Consider just one example. In 1976, *Logan's Run* opened in movie theaters across the United States. It described a hedonistic, corrupt, youth-oriented society in which life spans have strictly imposed limits. Their palms implanted with color-changing crystals, the "survivors of war, overpopulation and pollution" live for pleasure in a giant domed city but, when their crystals blink red, they must report for a fiery ritual of destruction.[3] Some refuse to submit to the all-controlling system and flee, becoming "runners" who seek new frontiers—in the book's version, this is an abandoned space colony—where more benign technologies offer a secular salvation.

With its oppressive technologies and environmentally shattered world, *Logan's Run* held up a mirror to the deepening concerns about the state of the environment and the effects of large technological systems on the individual citizen. *Westworld*, *Soylent Green, The Omega Man*, *A Clockwork Orange, Silent Running, Planet of the Apes*, the BBC television show *Doomwatch*—all projected similar anxiety about ecocatastrophe and technological doom. After all, this was Hollywood's era of the big-budget disaster epic.[4] Verging at times on apocalyptic millenarianism, these expressions of pop culture captured and contributed to the prevailing mood of pessimism about technology.

During the 1970s, the idea of limits—to technology, resources, energy, political power, wealth, even life itself—became a staple theme among journalists and academics. The most sensational articulation of this idea appeared in March 1972 when the Club of Rome presented its *Limits to Growth* report.[5] Although scientists and economists roundly criticized its methodology, *Limits* stimulated a fierce debate about whether it was necessary to adopt a steady-state economy, regulate population growth, and perhaps even curtail individual freedoms to avoid running out of resources (Garrett Hardin's famous essay on the tendency to exhaust shared resources, "The Tragedy of the Commons," had appeared just a few years earlier). Political discourse also reflected the theme of limits. When governor Jerry Brown addressed the California State Assembly in 1976, he intoned: "We are entering an era of limits."[6] After voters rejected "malaise" for the sunshine-drenched optimism of Ronald Reagan, Jimmy Carter stated that his entire presidency had been defined by political and economic limits.[7]

Some people, however, refused to accept the concept of limits, technological or otherwise. In response to the era's crises, technological enthusiasts with ties to California proposed alternative and seemingly radical solutions. This essay examines several communities of people who saw opportunity in an era of renewed technological enthusiasm. Starting in the 1970s, radical new visions of the technological future emerged from the California scene. Futuristic exploratory technologies such as space colonization, nanotechnology, and life extension captured the public's imagination. These ideas also helped stimulate the creation of privately funded research institutes and investment from high-tech entrepreneurs. The result was a distinctive view of the technological future shaped, flavored, and informed by its California roots.

Some Broader Concepts

Before proceeding further, I'd like to discuss three concepts that shape my essay. First, the future. An odd topic for a historian, perhaps, but I am nonetheless fascinated by the unrealized visions of the technological future that litter the past. In the late 1960s and early 1970s, a proliferation of futuristic visions about technology coincided with a larger wave of concern, even obsession, about the future. A good deal of this thought originated in coastal California. For example, RAND (Research ANd Development Corporation), the first postwar future-oriented organization, had been based in Santa Monica for decades. In a golden age of research and writing about technological tomorrows, professional "futurologists" became well-paid celebrities sought out for their glib advice. Hugely popular books such as *Future Shock*, Alvin Toffler's 1970 bestseller, advised readers to brace for wrenching social changes as an old economy based on heavy industry gave way to a new one founded on information. The future also became an object of serious scholarly inquiry as economists, computer scientists, and sociologists attempted to understand the future more "scientifically" and proposed ways in which society might navigate toward alternate, more desirable futures.

Visions of the technological future inspired debate; they also provoked skepticism and ridicule. The technological future was a contested rather than a neutral space.[8] In this "predictive space," different groups vied to claim and construct the future through their texts, their artifacts, and their activities while marginalizing others' proposed futures. This essay explores how and why particular "past futures" oriented around seemingly radical technologies achieved notoriety, if not success.

A second term I want to explain is technological enthusiasm. Enthusiasts were confident that technology was a beneficial force offering pragmatic solutions to economic and social problems. Although the field of the history of technology has matured greatly since Eugene Ferguson surveyed it in 1974, his warning that to ignore technological enthusiasm is to miss a "central motivating influence in technological development" still holds true.[9] Recently, scholars have reexamined how the American counterculture of the 1960s and early 1970s interacted with certain forms of science and technology.[10] This work, focused mostly on California's Bay Area, has challenged the once-prevailing view among historians that the early 1970s saw only a backlash against technology.

This essay adds to this rich story by considering technologies not directly connected with communes or early cyberculture. Space colonies and molecular manufacturing, for example, represented a continuation of earlier modernist ideals that valued mechanical progress, industrialization, and the manipulation of material stuff (as opposed to bits of information). Like earlier builders of large technological systems, the promoters of space colonies, artificial intelligence, life extension, and nanotechnology also believed in rationality, systems, and control. In their view, technology was an ameliorative and often deterministic force that would bring desirable social and economic change. Like the "mainstream scientists" who promoted supersonic commercial jets and missile defense systems, this essay's technological enthusiasts were rarely concerned with questions like "Is it commercially feasible?" and "Is it needed?" and instead asked: "Is it possible?"

This question of feasibility and the fondness for radical new technologies leads to my third issue: What should we call the people who invested so much of their lives in promoting their visions of the technological future? Unlike armchair futurists, these people—many of whom had advanced training in science or engineering—also carried out detailed research and engineering studies in order to realize their ideas. They made critical connections between their technical expertise and their visions of a more expansive future that would be created by the technologies they studied, designed, and promoted.

We lack a good word to describe someone who pursued this diverse set of activities. To help us better identify and understand these people, I use the neologism *visioneer*. Combining "visionary" and "engineer," it captures the hybridized nature of these technologists' activities. The visionary aspect is central—the people who populate my narrative weren't simply imagining a faster airplane or a new electronic gadget. They presented a vision of society as a whole being altered, shaped, and, quite often, improved, by the technologies they saw as necessary and even inevitable. The engineering element is just as, if not more, critical. Visioneers based their imaginings on detailed engineering studies and technical designs. They sought funding to pursue their ideas and promoted their visions to the public and policymakers in the hopes of generating publicity, acceptance, and perhaps even realization. They labored to engineer a foundation for their particular vision of the technological future—they *visioneered*.

Many visioneers, even those with university or industrial affiliations, carried out their visioneering away from the traditional research paths. They operated largely outside the funding and patronage system that supports most mainstream American scientists and engineers. Sometimes this was by choice, as being an outsider provided the freedom to explore without oversight and peer review. But even for those who sought it, the legitimacy that might come with federal monies could prove elusive. Instead, funding often came from an ad hoc array of sources—venture capitalists, wealthy entrepreneurs, private foundations, curious citizens, and grassroots organizations. These limitations and even ostracism from the mainstream often consigned visioneers to technological margins.

These visioneers and the often-overlapping communities of researchers, futurists, and entrepreneurs they attracted typically existed at a ragged border between scientific fact, technological possibility, and speculation. One must assess the activities of the technological enthusiasts described here in the context of their time, not by the extent of their success. Perhaps, as one of my characters suggested, the best term for their activities might be "exploratory engineering"—designing things that cannot be built with current technologies.[11] Much of their work was devoted to presenting and debating their ideas via a diverse array of writings. As a result, one way to understand these people's activities is to consider them as constituting one or more, sometimes overlapping, *textual communities*.[12] A core set of canonical writings about technology and future had accreted in the postwar years, becoming the common currency of futurists of various stripes. Members of futurist textual communities communicated with each other through newsletters, articles, e-mail, and websites, building on and referencing this canon. Constructing a common set of writings helped them to create a shared vision of the future and build social networks for advocacy and promotion. By providing common reference points and a set of shared common knowledge, these texts served as a "water cooler" around which this story's technological enthusiasts gathered.

Considerable overlap existed between those who promoted such divergent schemes as privately funded space exploration, radical ideas for nanotechnology, and various forms of life extension. In some cases, people migrated from one set of interests to others over time. And, by 1990, the frontier for unbounded technological optimism had already started to shift from outer space to cyberspace and virtual reality. In an era dominated by dot-coms and Sand Hill Road venture capitalists, the idea of actually making *stuff*—whether in outer space or in nano-space—came to be seen as almost quaint. As one of the seminal cyber-manifestos of the early 1990s said, "The central event of the 20th century is the overthrow of matter. . . . The powers of mind are everywhere ascendant over the brute force of things."[13] While this assertion was debatable—workers at semiconductor plants in the Santa Clara Valley might have seen this differently—this essay shows the continued migration of California-oriented technological enthusiasm to new frontiers and spaces.

The futures advocated by visioneers and other technological enthusiasts did not unfold as they predicted or hoped. This story matters, however, for reasons that transcend success or failure. It connects the recent past with a longer tradition of enthusiasm and utopian idealism that has characterized Americans' relationship to new technologies. If we liken today's networks of innovation to ecosystems, then we must be curious about the people and organizations that reside in its interstitial niches and edges.[14] This story illuminates visioneers' role in fostering new ideas and helping drive the familiar stages of excitement, expectation, and hype that mark many novel or emerging technologies. It may also help us understand the complexities of "innovation regions" like Silicon Valley or the emerging private spaceflight industry in the Southern California desert. More specifically, it forces us to address—as other contributors to this volume have done—the question of "California exceptionalism." A range of factors combined to make California an especially attractive place for visioneers to think about and advocate for their versions of the technological future.

Like the idealistic crusaders and writers of the nineteenth century, California's technological utopians wished to perfect society and alter the speed at which society changed.[15] They were not immune to the lures of profit, celebrity, and sensationalism. (As one pro-space entrepreneur boasted in 1980, "I'm going to become a billionaire. A lot of us are.")[16] These visioneers nonetheless believed that the technologies they advocated would transform society. As they imagined it, the future would break sharply with the past as humans mastered the ability to create new worlds, do atomic-scale engineering, and overcome their own biological limits. For them, the present was merely a prototype, a provisional plan of what would become the magnificent and eventual future.

Pursuing the High Frontier

Fiction writers and scientists had long harbored dreams of space-based utopian settlements that might provide the basis for new societies.[17] These futuristic ideas went hand-in-hand with the schemes for human settlements at the frozen poles or on the ocean floor that proliferated in the early 1960s. They also reflected the tide of optimistic "our-future-in-space" books that hit bookstores after *Sputnik 1* and *Explorer 1* rocketed into orbit. However, where previous visionaries offered only speculative descriptions of their utopias, physicist Gerard O'Neill used precise mathematical calculations and informed extrapolations of existing technological trends to develop his detailed designs for space settlements.

Trained as a high-energy physicist, O'Neill divided his time between Princeton University and the Stanford Linear Accelerator Center, where he participated in large-scale experiments. An instrumentalist in a culture that ruthlessly separated machine builders from experimentalists and theoreticians, O'Neill felt at home in the middle of big engineering projects.[18] O'Neill was also an avid science fiction fan, especially of Robert Heinlein, whom some libertarian writers called "the true bard of Southern California" with his "peculiar and unprecedented combination of rocket visions, a tough-minded individualism respectful of the military and iconoclastic free living."[19] O'Neill's later advocacy for privately funded space exploration reflected many of Heinlein's ideals.

Looking for a new career path in the mid-1960s, O'Neill tried to join NASA's scientist–astronaut program. When this did not pan out, O'Neill turned his long-standing interest in space exploration in new directions. Believing that the "days of blind trust in science and in progress were past," O'Neill asked his undergraduate physics students to focus on problems relevant to the environment and "the amelioration of the human condition."[20] In the fall of 1969, O'Neill offered a weekly seminar for his best students. To get them thinking about science in a more holistic fashion, he posed a thought experiment by asking: "Is the surface of a planet the right place for an expanding technological civilization?"

For decades, most futurists had imagined that human expansion into space would happen through settlements on the surface of other planets. However, as O'Neill discussed with his students, just overcoming gravity to get people and materials off the surface of a smaller planet like Mars would require a lot of energy. Instead of building settlements on another planet, he mused, why not build them in space?

O'Neill envisioned self-contained worlds, microcosms of larger Earth-bound systems. His detailed designs for self-regulating "closed worlds" demanded that he carefully take physics, structural engineering, energy requirements, systems ecology, and economics into account. Over time, O'Neill's visioneering matured into plans for self-enclosed ecological systems maintained through established engineering and cybernetic feedback principles. O'Neill's own descriptions of his space settlements were also reminiscent of communities and climates of coastal California, an area he had a special fondness for. One image from a study O'Neill took part in shows the "landscape" of a hypothetical space colony that looks strikingly like San Francisco, complete with an impressive bridge spanning a brilliant blue bay.[21]

Compared to the cost of the era's other major engineering projects, O'Neill's visioneering didn't seem impossible. NASA's Apollo program cost about $25 billion, while the space shuttle and the Trans-Alaska

Pipeline were each predicted to need billions more. Even more extreme were Nixon-era plans for national energy self-sufficiency, which analysts predicted could cost some $500 billion.[22] O'Neill estimated (using several optimistic assumptions, including NASA's own cost projections) that the price tag for building the first space colony would be about $30 billion. After drawing down the national purse to explore the moon, O'Neill claimed it was "now time to cash in on Apollo."[23]

Over the next five years, O'Neill refined his visioneering and presented it at campuses on both coasts. Seeking to expand his audience, O'Neill brought a small group of people together in May 1974 at Princeton for an inaugural meeting on "space manufacturing facilities." The Bay Area–based Point Foundation, started by counterculture icon Stewart Brand, provided seed funding. Brand, who had once lobbied NASA to take a photograph of the "whole earth" from space, developed an interest in space colonies because of this meeting.[24] *The New York Times* featured the Princeton meeting on its front page and media coverage of O'Neill's idea blossomed in other mainstream newspapers and magazines.[25] The next summer, Stanford University and NASA's Ames Research Center hosted O'Neill and thirty other enthusiasts—scientists, engineers, and students—while they did a broader study "of how people might permanently sustain life in space on a large scale."[26]

By the mid-1970s, O'Neill had become a minor celebrity, invited to testify before Congress about his plans for human settlements in space and regularly profiled in mainstream publications. His appearances on national talk shows with Merv Griffin and Johnny Carson popularized the space colony idea for an even wider audience.[27] *The High Frontier*, in which he laid out his ideas in full, won Phi Beta Kappa's award for the best science book of 1977 and set off a flood of publications by other authors that discussed the idea of people living in space.[28] That same year, O'Neill started the Space Studies Institute to direct funding from private donors toward research for space settlements and manufacturing.

O'Neill's advocacy and visibility also catalyzed a boom in pro-space activity in the late 1970s. By 1980, dozens of pro-space groups had formed; together they claimed some 40,000 members, a number that had tripled two years later.[29] The western United States was home to much of this grassroots organizational activity: about a third of these groups were based in California. Part of this interest, of course, can be traced to California's deep economic and historic ties to the aerospace industry as well as the presence of NASA centers like Ames and the Jet Propulsion Laboratory.

The L5 Society was one of the pro-space groups launched in the 1970s. Keith Henson and Carolyn Meinel, two O'Neill devotees, started what became a national organization in Tucson, Arizona. The name of the group came from O'Neill's idea of putting a space colony at one of the Lagrangian points—places in space where gravitational forces are balanced so that objects there remain in a relatively stable position.[30] L5's membership was relatively small, never more than 5,000 people or so. But it was bolstered by local chapters in the Bay Area, San Diego, and Los Angeles. One member described the community as a "post-graduate camp for space nuts" whose members tended to be "young, well-educated, and receptive to new ideas."[31] More than two-thirds were under the age of thirty-five, most were single men, and about 70 percent had college degrees.[32] L5's membership wasn't limited to people in their twenties and thirties. At John Muir High School in Pasadena, Taylor Dark III and a few teenaged friends established their own L5 chapter. Their group grew to about thirty members—including Carl Feynman, son of Nobel laureate Richard Feynman—and took advantage of the school's proximity to Caltech and the Jet Propulsion Laboratory to invite speakers on space-related topics.[33]

O'Neill's ideas for space colonies and his advocacy for beaming solar-generated electricity to Earth via satellites attracted a great deal of interest from California's countercultural community. The ways in which O'Neill and his followers framed their interests reflected a sensitivity to ecological issues and social diversity blended with a high-tech, megasystems-oriented approach. Attention also came from fringe groups with interests in alternative technologies. Berkeley, for instance, was home to The Network, a small group that promoted the spacey ideas of Timothy Leary. After his release from being in jail on drug charges in 1976, Leary began to advocate a new agenda that he termed SMI^2LE, an acronym for "Space Migration, Intelligence Increase, Life Extension," which he described in his book *Neuropolitics*.[34]

To be fair, Leary's interpretations were far from O'Neill's visioneering, and the physicist was careful to distance himself from Leary. More serious debate about space settlements and the pro-space agenda was sparked by former Merry Prankster Stewart Brand. In the mid-1970s, Brand's new magazine, *CoEvolution Quarterly,* ran several articles and contentious opinion pieces about space settlements.[35] The magazine's coverage became a flashpoint, igniting conflict between technological enthusiasts like Brand and those opposed to the entire concept of humans in space.[36] As Brand summarized it, "The man-made idyll is too man-made, too idyllic or too ecologically unlikely—say the ired. It's a general representation of the natural scale of life attainable in a large rotating environment—say the inspired. Either way, it makes people jump."[37]

The letters that survive in Brand's personal papers attest to the impassioned debate that space colonies triggered. To some *CoEvolution* readers, the idea of living in space seemed a logical extension of the "back to the land" lifestyle that eschewed crowded urban environments for rural communes. Others were attracted to ultimate fantasies of escapism and the possibility for social experimentation with no authoritarian oversight. But for those who favored E. F. Schumacher's "small is beautiful" philosophy and ideals of "appropriate technology," space colonies provoked horror and outrage. Many counterculture leaders, including some of Brand's friends, harshly condemned the whole idea. Brand himself tried to remain neutral, but his diary notes show where his loyalty was. After seeing the first space shuttle at Rockwell International's factory in Palmdale, California, he wrote: "Technology, kiddo. This is to today what the great sailing ships were to their day. Get with the program or stick to your spinning wheel."[38]

Governor Jerry Brown noticed the public interest in space among his fellow Californians and was, of course, aware that aerospace was a central pillar of his state's economy. Brown met with O'Neill at meetings facilitated by Brand and asked former Apollo astronaut Russell Schweickart to be his science adviser. In August 1977, as the movie *Star Wars* sold out theaters nationwide, Brand, Schweickart, and O'Neill joined hundreds of other advocates from the space and science communities for the first California Space Day. In Brown's speech before the group at Los Angeles's Museum of Science and Industry, the ascetic language of limits and restricted opportunity that had characterized his public pronouncements was transformed. The governor said, "it is a world of limits but through respecting and reverencing the limits, endless possibilities emerge. . . . As for space colonies, it's not a question of whether—only when and how."[39] Brown later advocated for California and NASA to fund a satellite project that he and Schweickart had developed. He was lampooned for his efforts by Chicago columnist Mike Royko as "Governor Moonbeam," a moniker that hurt him politically for years.

Despite the criticism, Brown recognized the possibilities the commercial space sector offered. Many of the early private space companies that sprung up in the late 1970s and early 1980s called California home. For example, Santa Barbara hosted the Earthport project. The project's goal was to create a tax-free trade zone in conjunction with an equatorial (and privately run) launch site.[40] A few years later, the future of private space development looked even more promising when the Reagan administration began to encourage space commercialization and private launch capabilities.

James C. Bennett was among the people connected with the Earthport project. As a student at the University of Michigan, Bennett had been inspired by Heinlein, O'Neill, and New Right libertarianism and had wanted to "extend the narrative of settlement and expansion of America into space."[41] After moving to California, he got involved with L5 and then Earthport. Bennett soon fell in with Phil Salin, a Stanford business student and aficionado of libertarian Nobelist Friedrich Hayek, and his wife Gayle Pergamit. The three space entrepreneurs went on to form a company named ARC Technologies with Bevin McKinney, the director of California's Space Now Society. They later rechristened the company Starstruck ("stars truck"). A former Apple Computer executive took over as Starstruck's president as the company's technicians developed a rocket that could be launched at sea. Magazines like *Omni* and *Popular Science* regularly featured this forward-looking industry in their pages. The company's first successful launch took place in August 1984. The next year, Bennett helped start American Rocket Company, based in Camarillo, while McKinney cofounded another California-based space company and invented a hybrid rocket-helicopter craft.[42]

Bennett and McKinney were two of the early space entrepreneurs based in California. Some of their attempts were successful; the rocket motor technology Bennett's company developed, for example, eventually found its way into *SpaceShipOne*. Designed by maverick engineer Burt Rutan and funded by Microsoft billionaire Paul Allen, this California-built craft made the world's first privately funded human spaceflight in 2004, winning a $10 million purse offered by the X Prize Foundation. Spurred by Rutan's success, several more "NewSpace" companies then sprang up near his company's headquarters in the Antelope Valley. These start-ups melded the grassroots activism that Gerard O'Neill encouraged with a business ethos drawn from Silicon Valley's entrepreneurial culture.[43]

Although O'Neill's space colonies did not materialize as he had hoped, his idea that space exploration could be done outside the NASA funding pipeline took hold in California. Inspired by his vision, California became the home of the country's most active pro-space communities, with groups spanning the political and cultural spectrum. California-based libertarian entrepreneurs saw space as a place to explore new technologies and try to make a fortune. Some of the technological enthusiasm spilled over into other areas, where our story takes us next.

Building the Future, California-Style

The standard narrative for nanotechnology's history begins in Pasadena in December 1959. In his after-dinner speech to the American Physical Society, Caltech physicist and future Nobelist Richard P. Feynman described potential miniature technologies, all the way down to the near-atomic scale, that could be accomplished within the laws of physics.[44] Feynman himself never did any research that could be construed as nanoscience and, after some initial publicity, his talk faded into obscurity until growing interest in nanotechnology two decades later brought attention to it again.[45]

In 1986, it seemed as if the physicist's vision was being realized when Gerd Binnig and Heinrich Rohrer, researchers at an IBM research laboratory in Zurich, received the Nobel Prize for designing the scanning tunneling microscope. This instrument rendered a topological image of atoms on a computer screen.[46] Now that scientists could image atoms, the next milestone in realizing Feynman's rediscovered predictions was to manipulate them. In 1990, two researchers at IBM's Almaden Research Center in San Jose reported that they had positioned individual xenon atoms with "atomic precision" to spell "IBM."[47]

The denouement to the standard story unfolds in California as well. In January 2000, President Bill Clinton addressed a standing-room-only crowd at Caltech and announced a major new national initiative to fund nanoscale research. Governor Gray Davis followed suit with a $100 million state initiative to foster nanotechnology in California and, he hoped, to rival Silicon Valley's success with microchips.[48] The result was a flood of money to help foster "the next industrial revolution," as governments and companies around the world followed the United States's lead, pouring billions into nanotechnology.[49]

But there is another part of this history, which has its origins, not with Nobel Prize–winning scientists, but in the pro-space movement of the 1970s. Like many technological enthusiasts, K. Eric Drexler disliked the focus on "limits" that came to the fore with the Club of Rome's report. As an undergraduate at MIT, he was also inspired by O'Neill's proposal to move people and industry off the planet.

Born in 1955 in Alameda, California, Drexler got involved in the pro-space movement a few years after the Apollo program ended. While earning his undergraduate degree, Drexler worked as O'Neill's research assistant, participated in early conferences on space manufacturing, and contributed to the L5 Society's grassroots organizing efforts. Between 1975 and 1982, Drexler published an array of popular articles and technical papers on asteroid mining, solar sails, and other pro-space topics. Like O'Neill, Drexler combined his vision of the technological future with engineering. Stewart Brand featured two of Drexler's essays in his 1977 space colonies book (in which the young engineer predicted, "I probably won't die on this planet").[50]

In the late 1970s, inspired by Feynman's talk along with developments in microelectronics and protein engineering, Drexler became increasingly interested in what he called "molecular engineering."[51] In 1981, he presented the first formal articulation of his ideas in the *Proceedings of the National Academy of Sciences*. His article claimed that the ability to design protein molecules could lead to the manufacturing of molecular-scale devices that, in turn, could make "second-generation machines" and eventually build "devices and materials to complex atomic specifications." Drexler insisted that his exploratory engineering be "taken in the spirit of early work on the theoretical capabilities of computers, which did not attempt to predict such practical embodiments" as specific hardware components or software code.[52]

A skilled writer and polymath with a talent for explaining complicated concepts in an accessible fashion, Drexler soon took his ideas to a wider audience.[53] Offering an alternative to the methods of the microelectronics industry, which fashioned transistors and circuits from the top down, building up and carving away material with tools like lithography and vapor deposition, Drexler proposed making new devices "from the bottom up, putting every atom in its place." He went on to describe a general concept for "protein machines" which, directed by computer code, could be self-replicating. Able to build or construct almost anything, perhaps even able to repair cells, this technology could, Drexler thought, open a door to environmentally benign manufacturing and health applications. Long on enthusiastic ideas but short on specific scientific details, Drexler's early writings nonetheless offered an enthusiastic view of a technological future in which engineers had precise control over the material world.

In 1985, Drexler and his wife, Christine Peterson, who earned her degree in chemical engineering from MIT, left Massachusetts for California. After moving to Silicon Valley, Drexler completed *Engines of Creation*, a book summarizing his vision of the nanotechnological future. Like O'Neill's *The High Frontier*, *Engines* was written for nonspecialists interested in technology and its implications.[54] Marvin Minsky, an artificial intelligence guru at MIT who later supervised Drexler's doctoral work, provided an introduction, and *Engines* became the canonical text for what Drexler and others had begun to refer to as nanotechnology (*Time* called it the "bible of nanotechnologists").[55] However, *Engines* did not limit itself solely to nanotechnology. Drexler's book presented a freewheeling discussion that regular readers of *Omni* and other magazines geared toward technological enthusiasts would have found familiar: artificial intelligence, self-replicating machines, life extension, technological forecasting, advances in computer technology, and space exploration all received discussion.

Drexler's ideas have changed notably in their focus and emphasis over the past twenty-five years, and a full treatment is outside the scope of this essay. But his experiences suggest the challenges radical technological enthusiasts faced. In the late 1980s, Drexler's visioneering received a tremendous amount of coverage in magazines and newspapers and served as a nucleus for the community that was coalescing around nanotechnology. New technology-oriented magazines like *Mondo 2000* and *Wired* that catered strongly to Silicon Valley *digerati* provided positive coverage of the Drexlerian visions for nanotechnology, as did mainstream venues like *Time*, *Fortune*, and *The Economist*. However, the publicity and popularization of his ideas, compounded by the fact that Drexler was not doing traditional lab research, made him a controversial figure. By the early 1990s, "the apostle of nanotechnology" had become a lightning rod for praise and scorn from fellow scientists.[56] When mainstream scientists and policy makers put together the National Nanotechnology Initiative in the late 1990s, they largely ignored Drexler's intellectual and popularizing contributions.

Regardless of his reception by the mainstream science community, Drexler's advocacy of nanotechnology took place in a very specific California context. The same year that *Engines of Creation* was published, Drexler and Peterson established the nonprofit Foresight Institute in Palo Alto. While nanotechnology was the group's major focus, the masthead from Foresight's first newsletter—"Preparing for Future Technologies"—spoke to broader interests. Peterson, for example, held a long-standing interest in environmental applications and, like Drexler, had been active with the L5 Society for years.[57] Well into the 1990s, Foresight was arguably the most advanced and outspoken group promoting nanotechnology. The organization regularly hosted conferences, sponsored by companies like Apple and Sun Microsystems, that brought together mainstream scientists, Silicon Valley executives, and a diverse group of technological enthusiasts. Drexler, Peterson, and other Foresight leaders were also successful fund-raisers and, by 1993, were able to offer substantial prizes, named after Feynman, for experimental and theoretical work that advanced "the construction of atomically-precise products through the use of molecular machine systems."[58] Winners over the years included university and corporate researchers; the prizes enabled Foresight to provide a bridge between mainstream scientific research and future-oriented exploratory engineering for several years.

In building Foresight's membership, Drexler and Peterson initially recruited from the community they knew best: the pro-space movement. At the same time, they wanted to avoid some of the problems that they had witnessed with pro-space groups like L5. "I think that L5 and the Space Studies Institute were used as a mine for lessons learned rather than an exact template," said Jim Bennett, a space entrepreneur who helped Drexler and Peterson launch Foresight. "We wanted a non-profit organization to deal with the ideas. We didn't want it to be as mass-movement oriented as L5."[59]

Foresight also attracted people from Bay Area technology communities, especially Silicon Valley's extensive software and computer businesses. These links were fostered by Drexler and Peterson's connections, personal as well as professional, with Project Xanadu, a software project that Theodor Holm Nelson had initiated years earlier. Nelson, a visioneer who coined the term "hypertext" in 1965, wanted to design and build a universal hypertext network that would make stored texts and graphics a commodity.[60] For years, Drexler advocated hypertext as a way to "speed the evolution of knowledge by aiding the expression, transmission, and evaluation of ideas."[61] Meanwhile, Nelson proposed building Xanadu—an early version of concept underlying the World Wide Web—with privately developed software and hardware and operating it for a profit. Xanadu's ambitions presaged the dot-com era's rise and collapse—*Wired* once characterized it as the "longest running vaporware project in the history of computing." Nonetheless, the project, which Drexler consulted for, was a classic example of California-based technological enthusiasm infused with both utopian and libertarian aspirations.[62]

In the late 1980s, Xanadu, based in the Palo Alto area, received considerable venture capital from John Walker. In the early 1980s, Walker's company Autodesk became a major Silicon Valley success story with its innovative computer-aided design software. Already a patron of Xanadu, Walker became a proponent of Drexler's ideas for nanotechnology after reading *Engines of Creation*. The entrepreneurial Walker saw an opportunity for Autodesk "to position ourselves to benefit from the advent of nanotechnology . . . surely one could not design atomically-precise structures without a molecular CAD system."[63] Another early donor to Foresight was Mitch Kapor, who cofounded Lotus Development Corporation, a 1980s-era software giant, as well as the digital rights–oriented Electronic Frontier Foundation.

With business and technical reputations well established in Silicon Valley's technological ecosystem, entrepreneurs like Walker and Kapor gave credibility to Drexler's visionary ideas. Donations supporting Drexler and Foresight also came from Silicon Valley's rank-and-file computer and software engineers. As Bennett recalled, quite often "it would just be some guy who had been a programmer at some company that had an IPO and he ended up with two or three million and he would give a few thousand. That was a real typical profile."[64]

Led by Peterson, Foresight established connections beyond Silicon Valley millionaires and venture capitalists. One of the first people Drexler and Peterson recruited to Foresight's board of directors was Stewart Brand. Brand had written favorably about Drexler and nanotechnology in his bestselling 1987 book on MIT's Media Lab.[65] That same year, Brand helped start the San Francisco–based Global Business Network (GBN) with futurist Peter Schwartz.[66] When Foresight held its first major nanotechnology conference at Stanford University in October 1989, GBN provided advice and connections to business leaders and high-tech experts.

Drexler's and Foresight's links with Silicon Valley's computer and cyberculture firmly places early nano-advocacy within a broader context of California-based technological enthusiasm. Drexler, in fact, received some of his staunchest support from Silicon Valley communities immersed in computer hardware, software, and biotechnology. Cybernetics principles, artificial intelligence, biotechnological analogies, and computer control all figured prominently in the Drexlerian view of nanotechnology. The autodidactic Drexler kept himself up to date with cutting-edge developments in software, artificial intelligence, and computer technology. He spoke widely on these topics in the Bay Area and, in the spring of 1988, offered a class at Stanford University (Nanotechnology and Exploratory Engineering) that was sponsored by Nils Nilsson, a professor in the school's Computer Science Department.

As many of Drexler's exploratory engineering devices could not be built in the laboratory, computer modeling of nano-systems became an important alternative path to supply a proof of concept. Much of this work was done at Silicon Valley–connected venues, such as Xerox PARC and NASA's Ames Research Center, on carbon-based systems and hypothetical nano-machines.[67] The strong support Drexler received from the computer community helps explain why the Association of American Publishers named Drexler's second book, *Nanosystems*, as 1992's best book in computer science (rather than in engineering or chemistry).[68]

Why did the Drexlerian vision of nanotechnology appeal to so many in Silicon Valley? "They are used to thinking of things digitally," Foresight executive Christine Peterson explained, "used to using an engineering approach, used to controlling discrete things. And they know the power of that. They also know the difficulty of that. So they love the idea that they could do with atoms what you can do with bits."[69] Moreover, nanotechnology seemed to be the natural inheritor of the success California's computer and biotechnology industries already enjoyed. In this framework, technologies improved continuously at a rate dictated by Moore's Law and, every so often, a new idea—nanotechnology, perhaps—would appear to shatter prevailing paradigms.

Never Say Die

The idea that atoms and computer bits were related, perhaps even interchangeable, transports us to another community of visioneers and the enthusiasts they attracted—people advocating technologically enabled life extension. For some people, this meant longevity via caloric restriction or, more boldly, cryonics—the preservation of one's body or brain at very low temperatures at death in the hopes that future medical advances might be able to bring about revival. Other people talked about the more radical possibility of uploading one's memories and life experiences into a computer.

Whatever the path that brought individuals to the cause, after 1970 California was home to one of the most active communities in the world devoted to life extension. And, more importantly for our story, many of these people had close ties to California's high-tech sectors. Again, this history is incredibly rich and I can just touch on a few key episodes that connect to my broader story of California-based technological enthusiasm. The idea of people going into cold-induced suspended animation has long been a staple of fiction and films, especially those depicting long-term travel in space. Think of the astronauts in their cold-induced suspension whom the HAL computer "deanimates" in Kubrick's 1968 film *2001: A Space Odyssey*, or "Space Seed," an episode of the television show *Star Trek* that mixed genetic enhancement, eugenics, and cryonic suspension.

Even rocket pioneer Robert Goddard speculated about "generation ships" that might one day carry people, their life functions suspended, far out into space. "It has long been known," he once wrote, "that protoplasm can remain inanimate for great periods of time, and can also withstand great cold, if in the granular state."[70]

As the Space Race continued through the 1960s, these ideas were discussed seriously by reputable scientists at established institutions. For example, even before Yuri Gagarin and Alan Shepard left the Earth's atmosphere, medical researchers discussed the possibility of lowering a person's metabolic rate in order to permit long-term space travel, coining the word "cyborg" in the process.[71] A few years later, *Physics Today* published Gerald Feinberg's "Physics and Life Prolongation." A respected scientist at Columbia University whose theoretical research included hypothetical faster-than-light particles called tachyons, Feinberg noted that "freezing and storing at low temperatures might lead to many new potentialities for the human race."[72] While these publications helped create a wider audience for the notion, mainstream scientists still gave cryonics a chilly reception.[73]

Although proponents readily acknowledged cryonics was speculative, it still became front-page news in January 1967 when reporters announced that a Californian was the first person frozen for a "future revival experiment." The man in question was not Walt Disney, as urban legends might have it, but James H. Bedford, a seventy-three-year-old former psychology professor from Glendale.[74] After Bedford was pronounced dead (his last words reportedly were "I'm feeling better"), members of the Cryonics Society of California injected him with an anticoagulant and placed him in a metal "cryo-capsule" filled with liquid nitrogen. The experiment had been anticipated by science fiction writer and futurist Frederik Pohl, who, just a few weeks after Bedford's hibernation, told insurance industry executives to brace themselves for the "$30 trillion market of the future" by writing policies to cover cryonic suspension."[75]

Soon after its first "experiment," the Cryonics Society of California, a Southern California group with a few hundred members, announced plans to open a twenty-person storage facility in the Los Angeles area. A much larger facility was anticipated in Barstow for patients willing to pay up to $20,000 for the procedure.[76] New organizations popped up to support the growing community. For example, Fred Chamberlain, an employee at the Jet Propulsion Laboratory, started a company called Manrise in La Canada with his partner Linda. In 1972, they self-published one of the first manuals for cryopreservation.[77] The Chamberlains went on to form the Alcor Society for Solid State Hypothermia, which was based in the Riverside area before relocating in the 1990s to Scottsdale, Arizona.[78] Over the next three decades, groups like Alcor promoted their particular vision of the technological future as well as research and technical studies that they claimed helped support their ideas.

In the 1970s, many cryonics advocates came from regions with established high-tech industries. These included the Los Angeles and Silicon Valley areas, which shared a passion for technology, sometimes seen literally as a potential savior, and an unabashed faith in the future. As the *Los Angeles Times* reported in 1972: "Cryonics leaders talk about [the future] with a passion bordering on reverence. The future, they say, belongs to science. The Golden Age of Biomedical Technology is at hand."[79]

To make their case, advocates of cryonics cited twentieth-century progress in medicine and technology—space exploration and the nascent field of genetic engineering were typical examples. To them, these rapid advances were general evidence that future technologies would offer some means to revive them from their preserved state.[80] But exactly how cryo-nauts might experience a high-tech revival was largely left unexplained at first. However, a potential answer to this question appeared in the mid-1980s—nanotechnology.

Drexler's first articles (as well as an entire chapter in *Engines of Creation*) discussed how future molecular devices might repair frozen or damaged tissue.[81] As a result, along with Silicon Valley's computer programmers, the cryonics community was one of the first to enthusiastically embrace speculation about the possibilities of nanotechnology. Advocates of life extension exchanged optimistic updates about the implications of nanotechnology in their small-circulation newsletters, via e-mail, and on electronic bulletin boards. For example, *Cryonics*, a monthly newsletter published by Alcor, mentioned "molecular engineering" as one answer to the question "how will we be revived" just two years before *Engines* was published.[82] Throughout the 1980s and into the 1990s, *Cryonics* and similar publications regularly featured articles and announcements about nanotechnology, while Drexler and others who promoted more radical visions of nanotechnology gave talks at cryonics conferences.[83]

Several people whose activities spanned mainstream academic research and the technological fringe supported the idea of life extension via nanotechnology. For example, Gerald Feinberg and Marvin Minsky vocally advocated cryonics and also served on the Foresight Institute's board. And Drexler solicited comments on early drafts of *Engines of*

Creation from friends and colleagues intrigued by life extension technologies as well as space exploration, hypertext, and artificial intelligence. The book's acknowledgments reflect these overlapping interests. Drexler, in other words, helped link the communities of molecular engineering and life extension, just as he had earlier helped connect futuristic space exploration ideas with nanotechnology.

The enthusiasm life extension advocates had for the more radical versions of nanotechnology did not help Drexler win converts among mainstream academic scientists. As one Stanford engineering professor said in 1991, "I don't think he should be taken seriously. He's too far out."[84] Nonetheless, futuristic medical applications such as cell repair became a staple part of how the mainstream media presented nanotechnology in the late 1980s and into the 1990s. A standard "device" that appeared in many magazine articles was the "nanobot"—a term Drexler himself did not use—which was depicted as a miniature machine that could "swim through the bloodstream fighting viruses."[85]

Californians continued to make up the largest fraction of Alcor's membership, and enrollment climbed throughout the late 1980s as general technological optimism grew, spurred by new information technologies.[86] Like space entrepreneurship and molecular engineering, the possibility of life extension via cryonics found an especially warm reception in Silicon Valley's high-tech culture. As a feature in the *San Jose Mercury News* reported, there was a logical reason why cryonics appealed to Silicon Valley types—for them, "technology is everything." The article went on to profile several "nerds on ice," including people from the Xanadu software project. "Techies," one of them explained, "will accept and dive into things before it is widely accepted."[87]

The Silicon Valley environment and the technologies flowing from it also helped foster another strand of immortality-via-technology writings. This was the concept of "uploading." The idea, suggested decades earlier in John Desmond Bernal's 1929 book of visionary technology, *The World, The Flesh, and the Devil*, was that, one day, people, having merged their bodies with machines, might transfer their memories and personality into a machine and therefore achieve a form of life extension. This idea implied a strongly mechanistic view of the mind, along the lines of that described by artificial intelligence researchers like Marvin Minsky. While the concept had been discussed for decades, the rapidly improving speed and memory capacity of 1990s computers suggested it might really be possible. As one proponent said, "Immortality is mathematical, not mystical."[88] Enthusiasts on California's technological borderlands saw death, like space, as yet another frontier to be overcome. Along with Aimee Semple McPherson's evangelism, Jack Parsons's occult activities, and the merging of quantum physics with New Age beliefs at Esalen, the interest in life extension suggests the diverse ways in which spirituality has co-existed with science and technology in California.

Raymond Kurzweil is an excellent example of a visioneer whose ideas for the technological future also have a quasi-spiritual aspect. Unaffiliated with any university, Kurzweil has outstanding credentials in the technology and venture capital communities. After graduating from MIT (Marvin Minsky was his mentor), he became a highly successful inventor of devices like a print-to-speech reading machine before receiving the National Medal of Technology from President Clinton in 1999.

In addition to his profitable "mainstream" engineering activities, Kurzweil is also one of the most visible promoters of the "technological singularity." Discussed among technological enthusiasts for several years, the idea received considerably more attention after the publication of Kurzweil's 2005 book *The Singularity Is Near: When Humans Transcend Biology*.[89] Kurzweil envisions a future in which "machines become more like humans—programmed with replicated brain synapses that re-create the ability to respond appropriately to human emotion, and humans become more like machines—our biological bodies and brains enhanced with billions of 'nanobots,' swarms of microscopic robots transporting us in and out of virtual reality."[90] The scenarios of radical technological convergence that Kurzweil and other "transhumanists" describe represent a form of secular millenarianism in which visions of the future are built on extrapolations of today's frontier engineering.[91]

Mainstream science promoters have not ignored these radical ideas about the technological future. Mihail C. Roco, a program manager at the National Science Foundation, for instance, has described the coming "convergence" of nanotechnology with biotechnology, information technology, and cognitive science, a combination that could produce a "golden age . . . an epochal turning point in human history." As one attendee at a 2002 meeting organized by the NSF said, "If the Cognitive Scientists can think it, the Nano people can build it, the Bio people can implement it, and the IT people can monitor and control it." Espousing a sweeping understanding of history predicated on an unshakable belief in technological progress, Roco imagines a possible future in which humanity is poised "at the threshold of a New Renaissance of science and technology."[92]

Whether this convergence of radical technologies is a real trend remains to be seen. But, in early 2009, Kurzweil and Peter Diamandis, founder of the X Prize Foundation, announced that they were starting Singularity University to facilitate the use of "exponentially advancing technologies" to address "humanity's grand challenges."[93] Based at NASA's Ames Research Center (once home to Gerard O'Neill's space colony studies and early work on computational nanotechnology), funded by Google, and aimed at students and Silicon Valley executives, the Singularity University and entities like it suggest a Californian convergence of past and future visioneering.[94]

Visions of the technological future changed markedly between O'Neill's advocacy of space settlements and Kurzweil's predictions about technological "singularities" four decades later. Yet some common features and goals remained. Seen most broadly, all of the visioneers discussed here and the enthusiasts they attracted shared the idea that technology offered a sure path to social change. More specifically, they believed radical new technologies could enable individuals to acquire new capabilities, augment their physical and mental powers, and transcend their own biological limitations.

Throughout this period, these different threads of technological enthusiasm continued to receive strong support from a diverse array of individuals and private organizations in California's technological ecosystem. While I am not arguing for a "strong" version of California exceptionalism, the story presented here suggests that the state attracted and nurtured visioneers. One could, of course, take a mythopoetic perspective and explain the trend through the lens of California's fabled fondness for the future: people come to the Golden State seeking new beginnings, new frontiers, and a chance to reinvent themselves.

The state's history also played a role because it was one of very few places that people like Drexler and O'Neill could forge links with established high-tech industries such as microelectronics, biotechnology, and aerospace. Existing institutions in the state where exploratory engineering was accepted, ranging from top universities to research centers like NASA's Ames Research Center and Xerox PARC, served as sites around which technological enthusiasm could nucleate. Future-oriented organizations like the Global Business Network helped promote radical visions of the technological future and, at times, these ideas attracted attention and donations from businesspeople and entrepreneurs already anchored in the state's technological ecosystem.

Finally, the California context proved a fertile source for visioneers and their ideas about the technological future for political and ideological reasons. California was home to a "distinctively western libertarian sensibility" that combined a desire for social freedom, concern for the environment, and a fondness for free markets unrestrained by government regulation.[95] In the mid-1990s, a "Californian ideology" emerged that "promiscuously combines the free-wheeling spirit of the hippies and the entrepreneurial zeal of the yuppies . . . [and] a profound faith in the emancipatory potential of the new information technologies."[96] This faith in technology garnered lots of attention in the early 1990s from magazines like *Wired* and politicians on both sides of the aisle (Albert Gore and Newt Gingrich, for example) as well as critiques from writers who branded it "cyber-selfish."[97]

This libertarian-flavored zeal for technology pre-dated the arrival of cyberspace, however. Some of its roots can be found in the pro-space movement, which also helped foster advocates of nanotechnology and cryonics. Ideas for the private development of outer space in the 1970s, for example, blended left-leaning counterculture ideals with libertarian and New Right thinking. Some pro-space activists, for example, seeing parallels with the development of the nineteenth century frontier, were willing to have the military lead the charge into space.[98] The pro-space movement attracted support from Jerry Brown as well as Ronald Reagan before it was riven by debates over the militarization of space in the early 1980s. These uneasy alliances presaged the 1990s, when left- and right-wing pundits and political leaders alike expressed support for a new digital frontier unfettered by regulation and rules.

Looking beyond the borders of the Golden State, this thirty-year period of visioneering and technological enthusiasm helps us understand the history of technology in some new ways. It encourages a broader consideration, for example, of who contributes to innovation and novelty. Universities, corporate labs, venture capitalists, and so forth are often seen as constituting the core of a technological ecosystem. The visioneers I have described and the groups that formed around them often operated in the interstitial niches and at the edges of this ecosystem. But they made contributions that extend beyond the sometimes-overlapping, sometimes-insular textual communities that formed around radical imaginings of the technological future. If we want to understand how technological regions function, then we should also at least consider the activities of visioneers on the margins—or who were marginalized—but who nevertheless contributed ideas about what might be possible.

To borrow an analogy from astrophysics, we might imagine visioneers and groups advocating exploratory technologies as a form of "dark matter" surrounding the more visible "galaxy" of research done by mainstream scientists affiliated with universities and corporate labs. Their liminal research and propagandizing, existing on the threshold of respectability and academic visibility, can still exert a considerable pull on the public's imagination of the technological future.[99] Just as Wernher von Braun's appearances on the *Wonderful World of Disney* helped build public interest for space exploration in the 1950s, O'Neill's plans for space settlements stimulated public interest for new long-term goals in space.[100] One might also argue that O'Neill's vision of privately funded spaceflight took to the skies in 2004 when *SpaceShipOne* made its first flight over the Mojave Desert. By the same token, Drexler's ideas helped introduce the public to nanotechnology and stimulated interest in it among policy makers.[101]

The activities and interests of California's technological enthusiasts helped broader technological movements and interests coalesce into shapes and forms we can observe today. For example, people associated with the Foresight Institute, the Space Studies Institute, and Alcor published research results in some peer-reviewed journals. Moreover, technological enthusiasts like Gerard O'Neill, Eric Drexler, Christine Peterson, and Ray Kurzweil testified before Congress with an eye toward influencing policy makers. This is not to say, for example, that the thousands of researchers in labs around the world would not be doing nanotechnology today if not for Drexler. But it might be called something else or it might exist as a more fragmented research agenda.

Perhaps the enthusiasm of these visioneers and their supporters—an eagerness that, at times, evinced both naive and hubristic qualities—was misplaced. But many members of the scientific mainstream have also displayed similar characteristics. In the 1960s, Berkeley physicist Edward Teller advocated using nuclear explosions to carve out harbors and canals, after all, and few scientists were as connected to the establishment as he was.[102] Popular interest in technology has always had deep roots in imagination, while visions of the technological future have stimulated ideas that push the limits of the possible.[103] By taking into account the activities of the visioneers who advocated exploratory technologies, we gain a better appreciation of how the technological future was imagined, contested, and created in the Golden State and beyond.

This material is based upon work supported by the National Science Foundation under Grant No. SES 0531184. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. I would like to thank people who provided valuable research material or were interviewed for this work. These include Tasha O'Neill, Freeman Dyson, Christine Peterson, K. Eric Drexler, James C. Bennett, Conrad Schneiker, Ralph Merkle, Mark Miller, Robin Hanson, Stewart Brand, Trudy Bell, and Ben Bova.

Notes

1 Tom D. Crouch, *Aiming for the Stars: The Dreamers and Doers of the Space Age* (Washington, D.C.: Smithsonian Institution, 1999), 30.

2 James Fletcher in "Antitechnology Bias," *Air Force Magazine,* September 1971, 53; David Dickson, *Alternative Technology and the Politics of Technical Change* (Glasgow: Collins, 1974).

3 From the 1976 film's opening on-screen preamble; also, William F. Nolan and George Clayton Johnson, *Logan's Run* (New York: Dial, 1967).

4 William Graebner, "America's Poseidon Adventure: A Nation in Existential Despair," in *America in the Seventies*, ed. Beth Bailey and David Farber (Lawrence: University Press of Kansas, 2004), 157–80.

5 Donella H. Meadows et al., *The Limits to Growth* (New York: Universe Books, 1972).

6 Described in Roger Rapoport, *California Dreaming: The Political Odyssey of Pat and Jerry Brown* (Berkeley, Calif.: Nolo Press, 1982).

7 Robert M. Collins, *Transforming America: Politics and Culture in the Reagan Years* (New York: Columbia University Press, 2007), 21.

8 This argument appears in several of the essays in *Contested Futures: A Sociology of Prospective Techno-Science*, ed. Nik Brown, Brian Rappert, and Andrew Webster (Aldershot, U.K.: Ashgate, 2000), and *Technological Visions: The Hopes and Fears That Shape New Technologies*, ed. Marita Sturken, Douglas Thomas, and Sandra J. Ball-Rokeach (Philadelphia: Temple University Press, 2004).

9 Eugene Ferguson, "Toward a Discipline of the History of Technology," *Technology and Culture* 15 (1974): 3–30.

10 David Kaiser, *How the Hippies Saved Physics: Science, Counterculture, and the Quantum Revival* (New York: W. W. Norton, 2011); Andrew Kirk, *Counterculture Green: The Whole Earth Catalog and American Environmentalism* (Lawrence: University Press of Kansas, 2007); John Markoff, *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry* (New York: Viking, 2005); Fred Turner, *From Counterculture to Cyberculture: Stewart Brand, the Whole Earth Network, and the Rise of Digital Utopianism* (Chicago: University of Chicago Press, 2006); Eric J. Vettel, *Biotech: The Countercultural Origins of an Industry* (Philadelphia:

University of Pennsylvania Press, 2006) as well as my own book, forthcoming with Princeton University Press, on radical ideas for the technological future from 1970 to the present.

11 A term suggested by K. Eric Drexler in various works such as "Exploring Future Technologies," in *The Reality Club*, ed. John Brockman (New York, 1988), 129–50.

12 Here I expand on a term originally proposed by medieval history scholars. Textual communities "were groups which rallied around authoritative texts and their designated interpreters," with differences arising among groups over points of interpretation. In this view, the texts and their authors are central to claims of authority; from Carolyn Marvin, *When Old Technologies Were New: Thinking About Electrical Communication in the Late Nineteenth Century* (New York, 1988), 12–14. Marvin applies this notion to the history of discourse about technological literacy and the effort of electrical professionals to portray themselves as experts. The original treatment of this idea was Brian Stock's, in *The Implications of Literacy: Written Language and Models of Interpretation in the Eleventh and Twelfth Centuries* (Princeton, N.J.: Princeton University Press, 1983).

13 Esther Dyson et al., "Cyberspace and the American Dream: A Magna Carta for the Knowledge Age," *Future Insight* 1.2 (August 1994), Progress & Freedom Foundation website, http://www.pff.org/issues-pubs/futureinsights/fi1.2magnacarta.html.

14 A similar term used recently by a Silicon Valley executive is "innovation ecosystem." See Judy Estrin, *Closing the Innovation Gap: Reigniting the Spark of Creativity in a Global Economy* (New York: McGraw Hill, 2008).

15 There is not much historical research on technological utopianism after the mid-1970s; much of what has been written takes the opposite tack, focusing on dystopian aspects. For discussion of earlier eras, see Howard P. Segal, *Technological Utopianism in American Culture* (Chicago: University of Chicago Press, 1985). The essays in *Imagining Tomorrow: History, Technology, and the American Future*, ed. Joseph Corn (Cambridge, Mass.: MIT Press 1986), discuss more recent examples but don't venture much beyond the 1960s; a more general presentation is Jay Winter, *Dreams of Peace and Freedom: Utopian Moments in the Twentieth Century* (New Haven, Conn.: Yale University Press, 2008).

16 Quote from Keith Henson, a controversial pro-technology activist, in Ned Scharff, "Too Crowded Here? Why Not Fly into Space," *Washington Star*, November 3, 1977.

17 For an example, see Asif Siddiqi, "Imagining the Cosmos: Utopians, Mystics, and the Popular Culture of Spaceflight in Revolutionary Russia," *Osiris* 23 (2008): 260–88.

18 Elizabeth Paris. "Ringing in the New Physics: The Politics and Technology of Electron Colliders in the United States, 1956–1972" (PhD diss., University of Pittsburgh, 1999).

19 From a July 1, 2007 op-eEd in *The Los Angeles Times* by Brian Doherty, a writer for the libertarian magazine *Reason* (based in California).

20 Gerard K. O'Neill, *The High Frontier: Human Colonies in Space* (New York: Morrow, 1977), 235.

21 "Interior View with Long Suspension Bridge," NASA ID Number AC75–1883, available at "Space Colony Art from the 1970s" page, NASA Space Settlement Mirror Site, Space Settlement Nexus section, National Space Society website, http://www.nss.org/settlement/nasa/70sArt/AC75-1883.jpeg. Also, see Peder Anker, "The Ecological Colonization of Space," *Environmental History* 10, no. 2 (2005): 239–68.

22 "Transcript of State of the Union Address," *New York Times*, January 31, 1974, 20.

23 From testimony O'Neill gave to the congressional Subcommittee on Space Science and Applications on July 23, 1975; reprinted in *Space Colonies: A Coevolution Book*, ed. Stewart Brand (New York: Penguin, 1977).

24 Robert Poole, *Earthrise: How Man First Saw the Earth* (New Haven, Conn.: Yale University Press, 2008).

25 Walter Sullivan, "Proposal for Human Colonies in Space Is Hailed by Scientists as Feasible Now," *New York Times*, May 13, 1974. Also, Gerard K. O'Neill, "The Colonization of Space," *Physics Today* 27 (1974): 32–40. Documents related to O'Neill's development of his space colony ideas are in his personal papers kept by his widow, Tasha O'Neill, who generously allowed me access.

26 From the preface of *Space Settlements: A Design Study*, NASA SP-413, ed. Richard D. Johnson and Charles Holbrow (Washington, D.C.: NASA, 1977).

27 O'Neill, *The High Frontier*; 1977 was also when O'Neill started the privately operated Space Studies Institute, a small outfit based in Princeton that supported technical studies to bootstrap space development.

28 Further discussion of O'Neill's ideas can be found in chap. 5 of De Witt Douglas Kilgore, *Astrofuturism: Science, Race, and Visions of Utopia in Space* (Philadelphia: University of Pennsylvania Press, 2003); Michael A. G. Michaud, *Reaching for the High Frontier: The American Pro-Space Movement, 1972–1984* (New York: Praeger, 1986), presents excellent information on O'Neill and the pro-space movement in general, with less focus on larger historical context.

29 An overview of the pro-space boom is in chap. 8 of Michaud, *Reaching for the High Frontier*, which draws a great deal on original research by science writer Trudy Bell, who published widely on the topic starting around 1980. An early example is "Space Activism," *Omni*, February 1981, 50–54.

30 Gerard K. O'Neill, "A Lagrangian Community," *Nature* 250 (1974): 636.

31 Hugh Millward. "Where is the Interest in Space Settlement?" *L5 News*, January 1980, 8–10.

32 Michaud, *Reaching for the High Frontier*, 112–14.

33 *L5 News*, November 1977, 9.

34 See, for example, "Starseed Seminar Aims for Mutation, Migration, Rejuvenation," *L5 News*, October 1976, 11. *Neuropolitics* also had contributions from science fiction writer Robert Anton Wilson and space entrepreneur George Koopman (both California residents).

35 Brand collected all these pieces as well as many of the letters he received on the subject and published them all in 1977. In addition, his professional correspondence, preserved in Stewart Brand papers, Stanford University Special Collections, Manuscripts Division, Palo Alto, Calif., M1237, series 1, captures the sense of debate that emerged over the issue in the mid-1970s.

36 Kirk, *Counterculture Green*, chap. 5.

37 From the preface to Brand, *Space Colonies*.

38 Stewart Brand, mid-1977 journal entry, box 18, folder 6, Stewart Brand papers (M1237), Stanford Special Collections, Stanford University.

39 From Brown's August 11, 1977 speech, box 10, folder 10, Whole Earth Catalog records (M1045), Stanford Special Collections, Stanford University.

40 Promotional materials and some correspondence on Earthport can be found in the Robert A. and Virginia G. Heinlein Papers (MS 95), University of California at Santa Cruz, Santa Cruz, Calif., PERS328-11 (Sabre Foundation/Earthport), available at The Robert A. and Virginia Heinlein Archives website, http://www.heinleinarchives.net/upload/index.php. Santa Barbara in the 1970s was also home to *Reason Magazine*, a libertarian magazine now published in Los Angeles.

41 James C. Bennett, interview with the author, July 19, 2007. A more formal version of this space-libertarian ideology can be found in Edward L. Hudgins, *Space: The Free-Market Frontier* (Washington, D.C.: Cato Institute, 2002).

42 Andrew J. Butrica, *Single Stage to Orbit: Politics, Space Technology, and the Quest for Reusable Rocketry* (Baltimore, Md.: Johns Hopkins University Press, 2003), chap. 2. McKinney's work was described by cofounder Gary C. Hudson in "Insanely Great? or Just Plain Insane?" *Wired Magazine,* May 1996, available at Wired.com, http://www.wired.com/wired/archive/4.05/roton.html.

43 W. Patrick McCray, "From L5 to X Prize: California's Alternative Space Movement," in *Blue Sky Metropolis: The Aerospace Century in Southern California*, ed. Peter J. Westwick (Berkeley and San Marino, Calif.: University of California Press and Huntington Library, 2012).

44 Published as Richard P. Feynman, "There's Plenty of Room at the Bottom," *Engineering & Science* 23, no. 5 (February 1960): 22–36; see also Chris Toumey, "Apostolic Succession," *Engineering & Science* 68, no. 1 (2005): 16–23.

45 The word "nanotechnology" itself did not appear until 1974 and then only in an obscure proceedings of a Japanese industrial conference; Norio Taniguchi, "On the Basic Concept of 'Nano-Technology,'" in *Proceedings of the International Conference of Production Engineering* (Tokyo: Japan Society of Precision Engineering, 1974). Nevertheless, Feynman's address became a crucial touchstone for future advocates of nanotechnology.

46 In 1987, for example, Virgil Elings incorporated Digital Instruments in Santa Barbara, California. This was the first company to market a commercialized version of a scanning tunneling microscope, the "Nanoscope." Cyrus Mody has written widely on this topic; a good example is "Corporations, Universities, and Instrumental Communities: Commercializing Probe Microscopy,

1981–1996," *Technology and Culture* 47 (2006): 56–80.

47 D. M. Eigler and E. K. Schweizer, "Positioning Single Atoms with a Scanning Tunnelling Microscope," *Nature* 244 (1990): 524–26.

48 W. Patrick McCray, "Will Small Be Beautiful? Making Policies for Our Nanotech Future," *History and Technology* 21 (2005): 177–203.

49 This was a standard trope in early nanotech lobbying documents; see, e.g.: Office of the Press Secretary, The White House: "National Nanotechnology Initiative: Leading to the Next Industrial Revolution," press release, January 21, 2000, http://clinton4.nara.gov/WH/New/html/20000121_4.html.

50 Eric Drexler, letter published in Brand, *Space Colonies*, 104. Much of Drexler's career is documented in two rather sensationalist books by Ed Regis: *Great Mambo Chicken and the Transhuman Condition: Science Slightly over the Edge* (New York: Perseus, 1990) and *Nano: The Emerging Science of Nanotechnology; Remaking the World—Molecule by Molecule* (Boston: Little, Brown, 1995). Drexler disputes some of Regis's claims (although he has declined to specify what the inaccuracies are).

51 This term originally served as the title of a speculative 1955 article by Arthur von Hippel, an MIT professor who wrote about the design of future materials. Arthur von Hippel, "Molecular Engineering," *Science* 123 (1956): 315–17.

52 K. Eric Drexler, "Molecular Engineering: An Approach to the Development of General Capabilities for Molecular Manipulation," *Proceedings of the National Academy of Science* 79 (1981): 5275–78.

53 K. Eric Drexler. "Mightier Machines from Tiny Atoms May Someday Grow," *Smithsonian,* August 1982, 145–54.

54 K. Eric Drexler, *Engines of Creation: The Coming Era of Nanotechnology* (New York: Anchor Press, 1986); the book was originally published with a different subtitle—"Challenges and Choices of the Last Technological Revolution"—which hews closer to Drexler's original vision that his book be about technology in general, not specifically about nanotechnology.

55 Philip Elmer-DeWitt, "The Incredible Shrinking Machine," *Time*, November 20, 1989, 112.

56 Ivan Amato, "The Apostle of Nanotechnology," *Science* 254, no. 5036 (1991): 1310–11; also see Gary Stix, "Waiting for Breakthroughs," *Scientific American* 274, no. 4 (1996): 94–99.

57 Christine L. Peterson, interview with the author, November 28, 2006.

58 Described at the Foresight Institute's website at http://www.foresight.org/prize/.

59 James C. Bennett interview.

60 According to the *OED*, in 1965 Nelson wrote, "Let me introduce the word 'hypertext' to mean a body of written or pictorial material interconnected in such a complex way that it could not conveniently be presented or represented on paper." See also Theodor Holm Nelson, *Literary Machines* (self-published, 1980), and Daniel Rosenberg, "Electronic Memory," in *Histories of*

the Future, ed. Daniel Rosenberg and Susan Harding (Durham, N.C.: Duke University Press, 2005), 125–51.

61 From *Foresight Update* 2, originally published November 1987, available at http://www.foresight.org/Updates/Update02.

62 See Gary Wolf's lengthy 1995 article "The Curse of Xanadu" in *Wired*, http://www.wired.com/wired/archive/3.06/xanadu.html. Also see http://www.xanadu.com.au/ararat for Nelson's response.

63 John Walker discussed this at a 1990 talk he gave at an Autodesk technology forum called "Nanotechnology in Manufacturing." His recollections come from an online memoir at: http://www.fourmilab.ch/autofile/www/autofile.html.

64 James C. Bennett interview.

65 *The Media Lab: Inventing the Future at MIT* (New York: Viking, 1987), 225–26.

66 See Turner, *From Counterculture to Cyberculture,* for helpful discussion of GBN and Brand's role.

67 Ann Johnson, "Institutions for Simulations: The Case of Computational Nanotechnology," *Science Studies* 19 (2006): 35–51.

68 This was K. Eric Drexler*, Nanosystems: Molecular Machinery, Manufacturing, and Computation* (New York: Wiley, 1992).

69 Christine L. Peterson interview.

70 "The Great Migration," in vol. 3 of *The Papers of Robert H. Goddard*, ed. Robert Goddard and G. E. Pendray (New York: McGraw-Hill, 1970), 1611–12.

71 Manfred E. Clynes and Nathan S. Kline, "Cyborgs and Space," *Astronautics*, September 1960, 26–27, 74–76; "Spaceman Is Seen as Man-Machine," *New York Times*, May 22, 1960, 31.

72 Gerald Feinberg, "Physics and Life Prolongation," *Physics Today* 19 (1966): 45–48.

73 D. E. Goldman, "American Way of Life?," *Science* 145 (1964): 475–76.

74 David Larsen, "Cancer Victim's Body Frozen for Future Revival Experiment," *Los Angeles Times*, January 19, 1967. The story was also covered in the *New York Times* and described in a self-published book from 1968 called *We Froze the First Man*.

75 William H. Honan, "The Futurists Take over the Jules Verne Business," *New York Times*, April 9, 1967, M243.

76 Ken Lubas, "Cryonics Society's Facility for Frozen Death to Open," *Los Angeles Times*, April 20, 1969, B1.

77 Titled "Instructions for the Induction of Solid-State Hypothermia in Humans," it is available on the LifePact website at http://www.lifepact.com/mm/mrm001.htm.

78 Described on "Alcor's Mission" page of Alcor Life Extension Foundation's website, http://www.alcor.org/AboutAlcor/mission.htm#name.

79 A. Michael Aron, "The New Ice Age," *Los Angeles Times*, June 10, 1972, W7.

80 This form of reasoning has attracted ridicule. Michael Shermer describes its logical leaps in "Nano Nonsense and Cryonics," *Scientific American*, September 2001, 29: "Look how far we've come in just a century, believers argue—from the Wright brothers to Neil Armstrong in only 66 years. Extrapolate these trends out 1,000 years, or 10,000, and immortality is virtually certain."

81 Drexler, "Molecular Engineering" (1981) discusses "the eventual development of the ability to repair freezing damage [which] has consequences for the preservation of biological material today."

82 "Molecular Engineering," *Cryonics* 45 (April 1984): 5, at the "Cryonics Magazine" page, on the Alcor Life Extension Foundation website, at http://www.alcor.org/cryonics/cryonics8404.txt.

83 For example, Drexler gave a talk in May 1985 at the Lake Tahoe Life Extension Festival called "Molecular Technology and Cell Repair Machines," reprinted in the December 1985 issue of *Cryonics*, http://www.alcor.org/cryonics/cryonics8512.txt.

84 Calvin Quate, quoted in Andrew Pollack, "Atom by Atom, Scientists Build 'Invisible' Machines of the Future," *New York Times*, November 26, 1991.

85 According to the *OED*, "nanobot" entered the popular lexicon in 1989, three years after *Engines of Creation* was published; Brigitte Nerlich, "Powered by Imagination: Nanobots at the Science Photo Library," *Science as Culture* 17, no. 3 (2008): 269–92.

86 Membership in Alcor, for instance, tripled between 1987 and 1990. According to a 1990 article, of the twenty-six people frozen in the United States, twenty-four were in California; Michael Cieply, "They Freeze Death If Not Taxes," *Los Angeles Times*, September 9, 1990.

87 Tim Larimer, "The Next Ice Age," *West* (magazine supplement to the *San Jose Mercury News*), December 9, 1990, 17–26.

88 Quoted in Ed Regis, "Meet the Extropians," *Wired*, October 1994, on the Wired.com website, at http://www.wired.com/wired/archive/2.10/extropians.html.

89 Ray Kurzweil, *The Singularity Is Near: When Humans Transcend Biology* (New York: Viking, 2005).

90 Raymond Kurzweil, "Live Forever," *Psychology Today*, January/February 2000, http://www.psychologytoday.com/articles/200001/live-forever.

91 John M. Bozeman, "Technological Millenarianism in the United States," in *Millennium, Messiahs, and Mayhem: Contemporary Apocalyptic Movements*, ed. Thomas Robbins and Susan J. Palmer (New York: Routledge, 1997), 139–58.

92 Quoted in M. C. Roco and W. S. Bainbridge, "Converging Technologies for Improving Human Performance: Integrating from the Nanoscale," *Journal of Nanoparticle Research* 4 (2002): 281–95.

93 See the description on Singularity University's website, http://singularityu.org/about/overview.

94 California is home to several other groups that advocate similar ideas. For example, the Singularity Institute, which has the "development of friendly artificial intelligence" as its goal, is based in the Bay Area, as is the Acceleration Studies Foundation; http://singinst.org and http://www.accelerating.org.

95 Kirk, *Counterculture Green*, p. 16 and chap. 5.

96 The term appears in an essay by Richard Barbrook and Andy Cameron of the same name; this appeared in several online versions starting in 1995. Available at the "Research" page of the Hypermedia Research Centre website of the University of Westminster, http://www.hrc.wmin.ac.uk/theory-californianideology.html.

97 These political alignments are noted in Turner, *From Counterculture to Cyberculture*, and Paulina Borsook, *Cyberselfish: A Critical Romp through the Terribly Libertarian Culture of High Tech* (New York: PublicAffairs, 2000).

98 Andrew J. Butrica, "The 'Right' Stuff: The Reagan Revolution and the U.S. Space Program," in *Remembering the Space Age*, ed. Steven J. Dick (Washington, D.C.: NASA, 2008), 121–34.

99 I would like to thank Cyrus Mody, who suggested the "dark matter" analogy over the course of several conversations on this topic.

100 In 1985, former NASA administrator Thomas Paine invited O'Neill to serve on the National Commission on Space. A year later, the group's report presented a blueprint for space exploration that reflected many of O'Neill's concepts and beliefs. *Pioneering the Space Frontier: The Report of the National Commission on Space* (New York: Bantam Books, 1986).

101 In the early 1990s, when Nobelist Richard Smalley (the co-discoverer of carbon 60 "buckyballs" and certainly a member of the scientific mainstream) wanted to generate support for nanotechnology, he often referred to Drexler's writings.

102 Scott L. Kirsch, *Proving Grounds: Project Plowshare and the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, N.J.: Rutgers University Press, 2005).

103 Howard E. McCurdy, *Space and the American Imagination* (Washington, D.C.: Smithsonian Institution Press, 1997), and the essays in *Imagining Tomorrow*, ed. Corn.