INTRODUCTION

Visioneering Technological Futures

I am vitally interested in the future, because I am going to spend the rest of my life there.

—Charles F. Kettering, inventor and head of General Motors' corporate research, quoted in advertising campaign for *Omni* magazine, 1978

On August 11, 1977, some 1,100 invited guests trekked to the old Museum of Science and Industry in downtown Los Angeles and celebrated California's first Space Day. Space exploration was big news that summer. At theaters all across the United States, *Star Wars* was raking in millions of dollars as fans queued to see the epic space opera over and over. The upsurge of excitement about space wasn't limited to just the silver screen. Out in California's Mojave Desert, engineers were readying the space shuttle *Enterprise* for its first solo atmospheric flight. NASA had high hopes that America's human spaceflight program, stagnant since the end of the Apollo era, would be revived by its new "space truck."

Buttoned-down aerospace executives, anxious NASA managers, and cynical politicos mingled with celebrity scientists like astronomer Carl Sagan and oceanographer Jacques Cousteau in the museum's elegant rose-festooned garden. Sprinkled among the guests were real astronauts who had been to space and *Star Trek* fans who yearned to go. Counterculture icons like LSD guru Timothy Leary and *Whole Earth Catalog* publisher Stewart Brand enlivened the crowd, which swelled even more when California governor Edmund "Jerry" Brown and his entourage arrived.

Accompanied by a phalanx of journalists, the invitees moved into the museum's Progress Hall and took seats beneath suspended satellites and rockets left over from the triumphant days of the space race. But the audience had little interest in revisiting what

the United States had already accomplished in space. They wanted to hear about the future. And, for quite a few in the crowd, the future meant space colonies.

Princeton physicist Gerard O'Neill—tall and trim with a Beatles-style haircut and a preference for turtleneck sweaters underneath his favorite Harris tweed sports jacket—was a prime catalyst for the event. For years, O'Neill had designed and promoted the construction of massive earthlike habitats that would float free in outer space far from our home planet's gravitational pull. He began with simple drawings and back-of-the-envelope estimates. In time, O'Neill's concepts matured into sophisticated designs backed by detailed calculations that he disseminated and discussed with others who shared his passion. Sensing a rise in public interest, O'Neill was ready to put his plans into action.

Time, the physicist believed, was of the essence. O'Neill imagined that the "humanization of space" could provide a respite for a crowded, polluted, and energy-hungry planet.[1] In the future, space could be not just a government-run *program* for astronaut elites but a *place* where ordinary citizens could live and work. In early 1977, O'Neill gathered his plans and hopes for space colonization into an award-winning book called *The High Frontier*, and its publication ignited more interest in his ideas.[2]

A wildly eclectic assortment of speakers, diverse in their occupations as well as their opinions about humanity's future in space, took the podium at Space Day. Beat generation writer Michael McClure read a poem that reflected his hopes that ecology and technology could find a sense of unity in space. "Join me here," he said, "in this space that we invent from real stuff where we have never laughed, nor danced, nor sung before."[3] Other speakers echoed environmental themes by describing future satellites that could collect and beam down clean energy produced by efficiently collecting the boundless solar power found in space. Outside the hall, meanwhile, Timothy Leary pushed his psychedelic version of O'Neill's vision. "Now there is nowhere left for smart Americans to go but out into high orbit. I love that phrase—high orbit," Leary vamped to reporters. "We were talking about high orbit long before the space program."[4]

When it was O'Neill's turn to address the crowd, he refuted Carl Sagan's suggestion that future space exploration would best be left to robots and machines. Taking a cue from the summer's most popular movie, he announced that "it was time to stop R2-D2 from having all the fun" and critiqued America's current "timid" space ambitions. Instead, O'Neill championed a strategy of "direct human involvement," which he illustrated with dazzling images of life aboard space-based settlements of the future.[5]

But O'Neill could show off more than just inspiring pictures. He also displayed a working prototype of a "mass driver" that he had helped design and build. The device used electromagnetic fields to accelerate payloads to very high speeds. O'Neill envisioned a much larger machine—something students at the Massachusetts Institute of Technology were already working on—that could propel minerals from the moon or an asteroid out into space where they would be recovered and processed into materials for building settlements in space. Such would be the trees that settlers of the future would use to build the log cabins of the new frontier O'Neill imagined.

George Koopman, an independently wealthy Los Angeleno and occasional host of a New Age–inflected radio show about radical technologies, listened to the talks at Space Day. Koopman was a space enthusiast who, years later, would start a company that set out to make rockets. But, in 1977, Koopman was gathering information for the L5 Society, a grassroots pro-space group enthusiasts formed in response to O'Neill's vision. For Koopman, there was only one way to interpret what he heard: "We're going."[6]

Not everyone was as convinced. Underground artist R. Crumb, creator of '70s-era comics such as *Keep on Truckin'* and *Fritz the Cat*, was in the audience too. Space Day ("or whatever the hell it was called," he wrote) infuriated Crumb. The museum was just "a show room for aero-space corporations," while O'Neill and other space enthusiasts were a "smug bunch of hypocrits [*sic*]." That so many people were "falling for the space hype hook, line, and sinker" finally prompted Crumb to stalk out in disgust.[7]

While Crumb fumed outside the museum, he could have encountered laid-off workers waving signs proclaiming "Jobs on Earth, Not in Space" and "Brown, Hire an Earthling" that expressed more

terrestrial concerns. Within Jerry Brown's own cabinet, where support for "soft technologies" like solar power and wind energy ran high, one gubernatorial adviser grumbled, "This is disgusting. It's a technology worship session."[8] O'Neill's expansive vision for the humanization of space, which he believed offered profound environmental benefits, clearly had the power to infuriate as well as inspire.

When Jerry Brown spoke, he stood in front of a giant photo of the earth from space (courtesy of NASA) emblazoned with Space Day's motto: "California in the Space Age: An Era of Possibilities." The future Brown described, with energy beamed to earth from orbiting satellites and space settlements providing a "safety valve of unexplored frontiers," was drawn straight from O'Neill's vision.[9] Reflecting on the banner behind him, Brown 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."[10]

It was no accident that Brown used the word "limits." A national magazine titled its 1975 profile of Brown as "Learning to Live With Our Limits." A onetime Jesuit seminarian who professed a fondness for asceticism and Zen retreats, Brown often warned his constituents of new constraints unfamiliar to those accustomed to the Golden State's seemingly boundless prosperity. "This country is entering an era of limits," he proclaimed in a national television address during the 1976 presidential campaign. "We're all on it, Spaceship Earth, hurtling through the universe."[11] A cartoon in a Sacramento newspaper captured this dismal view of the future with a road sign announcing: "Entering California. Lower Your Expectations."[12]

In fact, "limits" emerged in the 1970s as one of the decade's watchwords. For more than two centuries, Americans had propelled themselves and their country into a technological torrent with enthusiasm that bordered on faith. Technology—the assembly line, the Bomb, the freeway, the silicon chip—had enabled the United States to become an economic, military, and cultural power. But, in the late 1960s, many Americans had started to loudly and sometimes violently question technology's ability to resolve soci-

ety's problems. Fears of environmental catastrophe and nuclear war coupled with anxieties about resource depletion and overpopulation had strained their optimism to the breaking point. By the time Nixon's presidency was embroiled in scandal, a new sense of the future, one constrained by limits and scarcity, had emerged.[13]

But Jerry Brown's use of the word "limits" in his speeches reflected more than an awareness that the political and economic power of California (and America) was not infinite. Brown's comments—indeed, the attitudes expressed by many at Space Day—were a direct response to an event that had happened five years earlier.

In the 1970s, reporters spilled much ink explaining the Club of Rome's origin and purpose. Descriptions ranged from a "loose aggregation" of elite jet-setters studying the "future of man and the earth" (albeit with "a certain smugness") to a group of "crackpots" who believed the planet's future depended on "a Copernican change of vision." In reality, its thirty-some members formed an "invisible college" of high-profile businessmen, politicians, and scientists. They held their first major meeting at the venerable Accademia dei Lincei in Rome, hence the group's name.[14]

In March 1972, the Club of Rome released an influential report called *The Limits to Growth*.[15] Announced with a media blitz aimed at policy makers and ambassadors, its "doomsday timetable" predicted an inevitable collapse of societies all around the planet unless politicians and business leaders had the courage to restrict the growth of populations, industrialization, and resource use.[16] Instead of continued expansion, it called for economic and ecological equilibrium commensurate with a species wholly dependent on limited planetary resources. Extensive computer-based calculations by researchers from MIT provided the Club of Rome with evidence needed to support its bleak assessment of the future.

Although many scientists and economists savaged the methodology that produced *Limits*, the Club of Rome's report sent a powerful message about the constraints on what technology could accomplish for the future. Released as a paperback book, *Limits* became a global sensation. Its troubling conclusions compelled more than eight million people to buy copies, and *Limits* was trans-

lated into some thirty languages. The ideas in *Limits* infiltrated popular culture as well, providing unsettling themes for movies, television shows, and fiction well into the Reagan era.

By the time Jerry Brown spoke at Space Day, "limits" was a term charged with conflicting meanings. For some, it meant austerity, self-denial, and living responsibly with a small planetary footprint. To others, limits meant narrowed options, restricted political freedoms, and vastly lower expectations as to what technology could offer Americans. To both groups, "limits" served as a shibboleth. Said in the right context and company, it told people which of these divergent views of the future you imagined.

There was a third point of view however. Some optimistic and entrepreneurial-minded scientists and engineers saw the notion of limits not as a warning or impediment but as a challenge. Was the future *really* going to be this dire? No, they said. Instead, they trusted that unexplored technological solutions could offer a reprieve or even an escape for the United States and perhaps the planet. However, the threat of economic, environmental, and planetary limits rumbling in the distance provided an essential foil against which to contrast their visions of a limitless future. As these scientists and engineers imagined it, the future would break sharply with the past when people mastered the ability to create new worlds and build new, powerful machines using nanotechnology. For them, the present, with its doomsayers agonizing over constraints, was merely a prototype, a provisional plan of what would become a magnificent and far less limited future.

This book explores how and why this select group of scientists and engineers developed their broad and expansive visions of how the future could be made radically different through as-yet-undeveloped technologies. It looks at how their visions for these technological futures were promoted, embraced, and rejected. Depictions of these futures and their enabling technologies fostered communities of enthusiasts who read about, debated, and helped publicize their ideas. Such imaginings of the future made possible by space colonization, for example, or radical nanotechnologies

attracted attention from journalists, artists, business leaders, and politicians. These visions also took hold in popular culture and helped create a picture for the public of what the future might be like. By the book's end, we'll see how some aspects of these imagined futures happened, although almost always not as their advocates imagined.

This book focuses on two particular visions of the future and the ensembles of technologies seen as critical to achieving them. Both imagined futures were catalyzed by advocates' belief that new technologies offered radical solutions that could defuse the threat of limits. One of these is Gerard O'Neill's ideas for settlements and factories in space, technologies he saw as an alternative to terrestrial limits, lifestyles, and manufacturing.

Although O'Neill shared a vision of space settlements, right down to how they might look, with "blue-skying" futurists and science fiction writers, his work differed from theirs in several important ways. First, where earlier visionaries offered descriptive speculations, O'Neill deployed extensive mathematical calculations and careful but bold extrapolations of existing technological trends to develop rigorously detailed plans for space settlements. Throughout the 1970s, he continued to refine and improve his initial designs, taking into account new data he collected and critiques from colleagues. O'Neill supplemented his pen-and-paper work by tirelessly promoting his vision to colleagues, interested citizens, politicians, and journalists. O'Neill's program for the humanization of space sparked a small-scale social movement in the wake of the Apollo program's termination. College students and other members of the baby boom generation proved especially vigorous supporters of a reinvigorated space program in which they imagined they could play a role.

One of these young adults was K. Eric Drexler. As an MIT undergraduate in the early 1970s, Drexler was drawn to O'Neill's ideas and designs for the humanization of space. Drexler went on to develop plans for lunar factories, solar sails, and methods to mine asteroids for mineral resources. Besides patenting some of his ideas, he also helped build the mass-driver prototype displayed at

California's Space Day. By his early twenties, Drexler was one of the L5 Society's most articulate and vocal advocates for an expanded human presence in space.

Starting in the late 1970s, however, Drexler began to envision a new technological frontier. Whereas space promised the infinitely vast, nanotechnology shifted attention toward the molecular scale. (A nanometer, a basic unit of nanotechnology, is a mere one-billionth of a meter or about the size of a sugar molecule and far smaller than a virus. Put another way, a nanometer is to a meter roughly what a child's marble is to the size of the earth.) Inspired by steady advances that engineers and scientists had made in microelectronics and molecular biology, Drexler blended and extrapolated these in new directions to imagine a future in which people designed and built nanoscale materials, structures, and machines with near-atomic precision.

Through popular books, articles, and technical papers, Drexler and his supporters described self-replicating "universal assemblers" that might one day refashion the material world "from the bottom up, putting every atom in its place."[17] The power of nanotechnology, Drexler predicted in his influential 1986 book *Engines of Creation*, could mean more efficient use of natural resources, manufacturing that was less environmentally destructive, and even the ultimate set of tools for reaching beyond the earth into space.[18] The fact that he titled one book chapter "Limits to Growth" and another "Engines of Abundance" speaks to the enduring effects of the Club of Rome's report. Well into the 1990s, Drexler, aided by articles about his ideas in magazines such as *Omni*, the *Economist*, and even *Reader's Digest*, successfully promoted nanotechnology even as some researchers refuted claims as to what sorts of nanoscale machines one could possibly build.

Space colonization and nanotechnology. At first sight they present an odd combination. But this pairing of technologies makes sense. For much of the twentieth century, space exploration was *the* archetypal technological frontier, the blank slate on which generations of engineers and schoolchildren projected their wildest dreams. But techno-dreaming shifted to new realms. By the late 1990s, following Drexler's popularization, researchers, venture

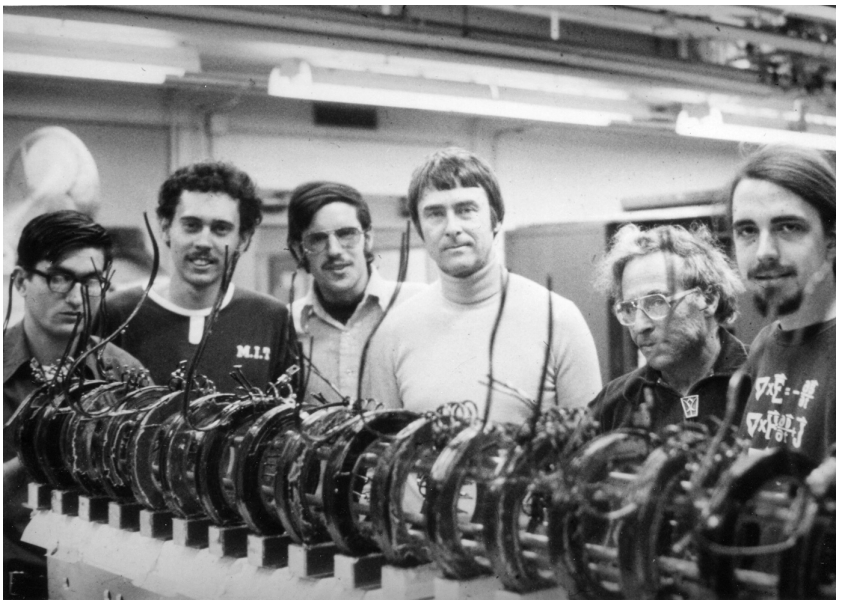

Figure I.1 Prototype mass driver, c. 1977, built at MIT, with (*from right*) MIT student K. Eric Drexler, MIT professor Henry Kolm, Princeton professor Gerard O'Neill, and three other MIT students. (Image courtesy of Tasha O'Neill.)

capitalists, and policy makers were declaring nanotechnology as the critical new technological frontier for the twenty-first century. The most radical schemes, while often popular with general readers, were resisted and ridiculed as impracticable. Yet aspects of these futuristic nano visions were co-opted into more mainstream plans for research and technology development.

Despite their vastly different scales, futuristic concepts for settlements in space and for nanotechnology both centered on the mastery of the material world through technology. This book shows how the two topics, their promoters, and the communities that coalesced around them overlapped and proved influential in surprising and unexpected ways. In both cases, proponents imagined building a limitless tomorrow that sidestepped catastrophist scenarios of the future to offer endless space to expand, an abundance of resources, and, in the most radical versions, the possibility of transcending the mortal limits of the human body itself.

Visioneers

O'Neill's and Drexler's work pushed far beyond speculation. This alone distinguishes them from futurists content to prognosticate from a podium. O'Neill, Drexler, and others like them used their training in science and engineering to undertake detailed design and engineering studies. As a result, O'Neill and Drexler could explore and develop their conceptions of an expansive future created by the technologies they studied, designed, and promoted. In some cases, their studies led to the creation of actual things: prototypes, models, patents, and computer simulations. Just as importantly, O'Neill and Drexler also built communities and networks that connected their ideas to interested citizens, writers, politicians, and business leaders.

We lack an appropriate term for someone who undertook such a diverse set of future-directed activities. To fill this gap, I propose *visioneer*. A neologism combining "visionary" and "engineer," this word captures the hybridized nature of these technologists' activities.[19] By using O'Neill and Drexler as archetypal examples, this book explores the role of visioneers over the last forty years as they proposed and promoted new technologies.

The visionary aspect is essential to understanding visioneers' motivation. O'Neill, Drexler, and the communities they helped foster imagined that their technologies could shape future societies, upend traditional economic models, and radically transform the human condition. These plans flirted with and sometimes embraced technological utopianism. Imagining the ramifications of settlements and factories in space or nanoscale machines was more ambitious, yet far more challenging to realize, than designing a faster airplane or new computer circuit. But visioneers' faith in a particular technological future provided a valuable and hard-won space in which other scientists and engineers could mobilize, explore, and push the limits of the possible.

The engineering and technical knowledge that underlies visioneers' work is equally critical. O'Neill and Drexler both drew on their academic backgrounds and experience in science and engi-

neering. Their detailed engineering and design studies underpinned speculations as to what the future could be like. Not content with just speculation, O'Neill, Drexler, and others who shared their visions did research to help advance the technologies central to building their imagined futures. Visioneering connects this emphasis on design, engineering, and construction to a more distant time horizon and an expansive view of a future determined by technology.

Even if they didn't have the physical or financial means to build a colony in space or self-replicating nano-assemblers, O'Neill and Drexler depicted evocative worlds through their books and articles. These writings attracted like-minded enthusiasts eager to imagine and perhaps live in these technological futures. Over time, a canon of visioneers' writings developed. These texts helped educate and define visioneers' communities while their supporters used them to launch further debate about what the future could be.

Sometimes, however, the popularity of visioneers' ideas and their writings proved problematic. Space colonies and nanoscale machines became indelibly associated in the public's mind with O'Neill and Drexler respectively. Publishing outside the specialized confines of peer-reviewed scientific journals produced tensions between the necessity of promotion and the inability to control its outcomes. Visioneers' successful popularizations attracted others eager to adopt or co-opt their ideas. Timothy Leary, for example, connected O'Neill-style space settlements to his own vision for how humans might purposefully evolve as a species, much to the physicist's unease.

As journalists paraphrased and repeated visioneers' ideas, some distortion was inevitable. Eric Drexler coined the term "gray goo," for example, to describe a hypothetical scenario in which self-replicating nanoscale machines consume the planet while making copies of themselves, but he gave the idea only glancing mention in *Engines of Creation*. Nonetheless, descriptions of uncontrolled, self-replicating "nanobots"—a term Drexler himself avoided—proliferated. These accounts helped define, for better or worse, how the public imagined a future in which Drexler's nanotechnology existed. Unable to maintain full control of their ideas, visioneers such as Drexler and O'Neill risked ostracism from main-

stream researchers who marginalized them to the "freak show that is the boundless-optimism school of technological forecasting."[20]

Like traditional engineering, visioneering requires money. Promoters of radical new technologies create a bricolage of patrons and supporters to finance their work. Many visioneers operated to some degree outside the patronage system that funds and supports conventional American scientists and engineers at universities, corporate labs, or federal facilities. Sometimes this was a deliberate choice, as it provided freedom without managerial oversight and peer review. In other cases, especially with Drexler, the legitimacy that might have come with federal monies and tenured professorships often proved elusive. Funding to pursue and explore O'Neill's space settlements and Drexler's nanotechnology was often ad hoc. Venture capitalists, wealthy entrepreneurs, and curious citizens all contributed in varying degrees. To help raise funds, both men set up nonprofit institutes that helped promote their visioneering. And, although it was less common, federal agencies like NASA and industrial research labs helped support some of the visioneering described in this book. But what primarily motivated both people and organizations to open up their minds and wallets was curiosity and, for some, the chance to get in on the ground floor of something potentially profitable. Like their patrons, visioneers stood to benefit from breakthroughs that helped validate their ideas, with potential rewards coming not just financially but also in the coin of enhanced credibility.

Technology, of course, involves much more than the tangible stuff—the cell phones, freeways, and antibiotics—that shapes our lives and the natural environment. In this book, "technology" represents the diverse ensemble of enabling activities and knowledge as well as the actual "things" themselves. This marks visioneering as something far from a solitary activity. Visioneers engaged in promotion, popularizing, and fund-raising that created and connected different communities while helping advance their broader visions. This heterogeneous engineering created durable social networks while popular explications of their ideas generated wider public interest.[21]

As we survey the overlapping histories of O'Neill's space colonies and Drexler's nanotechnology, we find a few people who

proved especially effective at helping get the message out. Stewart Brand, for example, used his magazine *CoEvolution Quarterly* to foster a debate about O'Neill's vision for the future. A decade later, Brand helped raise awareness of Drexler's ideas for molecular-scale manufacturing among business executives and technology pundits. Although not a visioneer as I've defined the term, Brand (and others like him) helped shape public awareness of visioneers' activities and ideas. Over time, the tools for promotion and advocacy changed. In the 1970s, O'Neill's supporters promoted the "humanization of space" with mimeographed newsletters, bumper stickers, and leaflets passed out at science fiction conventions. By the late 1990s, the communities that visioneers fostered could also interact with one another through e-mail, Web sites, and Internet newsgroups. These new tools amplified visioneers' messages as well as the chance of being distorted or attacked.

To sum: *visioneering* means developing a broad and comprehensive vision for how the future might be radically changed by technology, doing research and engineering to advance this vision, and promoting one's ideas to the public and policy makers in the hopes of generating attention and perhaps even realization. Throughout all these diverse activities, people like Drexler and O'Neill worked to build technical and social foundations for their own particular conceptions of the technological future. This book explores what such visioneering entailed, the ways in which it worked, and the places where it went astray.

The histories of science and technology offer other, earlier examples of people we might categorize as visioneers. For example, before World War Two, amateur rocket societies in Germany, the Soviet Union, and the United States blended rudimentary rocket engineering with romantic ideals of a future in which space travel would be routine.[22] Grassroots groups such as the American Rocket Society and the Verien für Raumschiffahrt (German Rocket Society) were inspired by theorists and dreamers, while the drive for space exploration and colonization drew in and drew upon the work of science fiction writers. A considerable amount of charlatanism surrounded these fledgling efforts as well. From this milieu emerged charismatic personalities—visioneers—like Wernher von Braun, Robert Goddard, and Frank Malina, who combined their

fascination with exploring new worlds with cutting metal, mixing chemicals, and drawing blueprints. Successfully launching their first rockets also meant selling the dream of spaceflight to the public and potential patrons. Von Braun long imagined ring-shaped space stations and missions to the moon and Mars. His skills at public relations *and* engineering made some of it come true, although at terrible cost to the enslaved workers who helped build Nazi V-2 rockets and the victims of missile attacks in Great Britain and Belgium.[23]

The visioneers' hybrid nature—a combination of futurist, researcher, and promoter—and the influence they sometimes attain compels us to consider how they interact with other actors in broader systems of technological innovation. Business executives and academics have often employed ecological metaphors to describe places where technological innovation occurs.[24] These complex and dynamic "ecosystems" are home to some familiar "species." These include established companies, universities, law firms, patent lawyers, entrepreneurs, investors, government funding agencies, the media, and, of course, scientists and engineers.

But we must also be curious about the visioneers who reside, as did O'Neill or Drexler, in the interstitial niches and edges of such technological ecosystems. Although this book makes no claim to analyze public or industrial policy, it does argue that visioneers, a species typically less acknowledged, are also important to the growth, diversification, and health of today's technological ecosystems. Such an evaluation demands an understanding of the past along with a measured consideration of the role of visioneers in fostering innovation and new ideas. This story also helps explain why utopian-tinted visions of the technological future flourish despite their predilection to mutate, get co-opted for other purposes, or simply disappoint.

Histories of the Future

The scenarios of the technological future this book explores originated with a fascination, even obsession, with the future that sur-

faced in the 1960s and continued into the following decade. When Senator Edward Kennedy said that "we must be pioneers in time, rather than space," people responded.[25] In 1966, a few people who saw the future as a new frontier formed the World Future Society. By 1974, its membership had climbed past fifteen thousand.[26]

Space exploration, the advent of microelectronics, the growing ubiquity of computers, and the ability to genetically engineer new organisms certainly sparked profound questions about the future. Darker currents in American society also contributed to Americans' tendency to look forward uneasily. Crises of confidence about the government and national power caused by Vietnam and Watergate coupled with inflation, oil shortages, and unemployment made people fearful for the future. One response to this apprehension and anxiety was to try to predict, with an aim toward managing, what the future had in store.

People have always looked *to* the future. But, in the late 1960s, a growing number of scientists, writers, and other experts were also looking *at* the future. Because America's economy, society, and politics appeared unstable, the technological future seemed an especially robust, even hopeful, place for speculation. American businesses started retaining specialists, including science fiction writers, to "plot the future much as medieval monarchs used to have court-astrologers around."[27] Techniques originally developed for Cold War military planning made their way to the corporate world. The growing availability of computers and a belief that complex economic and social situations could be modeled aided their acceptance.[28] The *Limits to Growth* report appeared at the end of a long process, mediated by data and computers, that aimed to discern what the future might hold.

Well into the 1970s, the "future" remained an object of serious scholarly inquiry. Interdisciplinary groups of economists, computer scientists, and sociologists attempted to understand it more "scientifically" and proposed ways for society to navigate toward more desirable futures.[29] Adding to this was the growing community of professional futurists. Paid for their informed predictions, these people gave particular attention to what the key technologies of the future would be.[30] In this golden age of contemplating tech-

nological tomorrows, professional "futurologists" became jet-setting celebrities handsomely compensated for their advice.[31] Millions of people bought Alvin Toffler's *Future Shock* (1970) and *The Third Wave* (1980). Toffler, a former editor for *Fortune*, described how modern society was poised between two technological eras, one of industry and another of information, and predicted abrupt changes catalyzed by technologies people needed to prepare for.[32] Futurists like Toffler and John Naisbitt, who wrote the best-seller *Megatrends*, don't qualify as visioneers as I'm using the term. Little detailed technical knowledge underpinned their ideas for the future, nor did they undertake design efforts or engineering to advance the technologies they spoke of.

However, the future that interested the people who populate this book was not next year's business cycle, nor was it some faraway world of the twenty-sixth century. Visioneers' imagined futures, shaped by technologies they helped promote, were just a few decades over the horizon, a time they hoped to personally experience. And even if space colonies or Drexler's nanomachines seemed to be far from realization, they served as political statements. These visions said something as to who was going to build the future, control it, and benefit from it. The future offered a blank space on time's map, a temporal vacuum in which to project one's hopes and fears. Creating visions of the future and the technologies that might help shape it is a political act as well as an exercise of imagination. But the future is not a neutral space. Inevitable disagreements as to what the future will be like and how it might be realized make the future a contested arena where diverse interests meet, debate, argue, and compromise.[33]

We see this dynamic at work today in debates over how to address broad challenges such as climate change. Some people maintain the viability of coal-fired power plants and others advocate renewable energies, while a smaller population envisions radical technologies like fuel cells or nuclear fusion as the power source of the future.[34] Each of these communities envisions, promotes, and works to advance a particular future and the technologies central to it. Influence among those with differing views of the future is rarely symmetrical. Not all futures are created equal. But under-

standing the history and processes of visioneering can help us get a sense of how we'll write tomorrow's future today.

In this book, we see how different individuals and the groups that coalesced around them vied to construct and claim the future through their writings, their designs, and their interactions with broader publics. In doing so, they often rejected other possible futures, especially those suggesting that the resources of the planet, the ingenuity of its people, and even our own life spans presented limits. To be sure, they also sometimes disagreed with members of their own communities.

Visioneers and the communities of researchers, futurists, and entrepreneurs they attracted often existed at the blurry border between scientific fact, technological possibility, and optimistic speculation. The difference between an eccentric inventor and a visionary entrepreneur is a fine one and often not distinguishable or appreciated at the time. One way to distinguish visioneers' ideas is that while they may have seemed fantastical, they were not impossible. Unlike time travel, designing a space colony violated no obvious physical laws. As one technology enthusiast put it, "Our ideas don't require any new physics to work . . . it's just that we follow chains of thinking much further along than most people are prepared to go."[35] As uncomfortable as visioneering may have made some mainstream scientists, no one conclusively exposed its unfeasibility.

As a historian, I am fascinated by past visions of the technological future. I'm less interested in adjudicating whether visioneers' plans for the future were correct or wrongheaded. What concerns me more is how visioneers conceived of and presented their ideas in response to the dire warnings in reports like *Limits to Growth*. What were their motives, hopes, and results? How did other technological communities react to their plans? How were these ideas brought to the public by journalists, science fiction writers, and popular culture? Can we detect ripples from their schemes in the broader American imagination? Although not always visible from the desks of federal science policy makers, I believe visioneers' influence was experienced as frissons of excitement, curiosity, and alarm among other scientists and the broader public. At the same

time, my interest is a critical one. As the book's title suggests, visioneers imagined a limitless future, an insistence that can appear naïve. Strictly speaking, there are limits. But the search for how to push past them has been a powerful motive force in the history of technology.

The technologies proposed by visioneers like O'Neill and Drexler existed at the margins of possibility. That was a key part of their attraction. Another clue to their seductiveness stemmed from their potential to solve seemingly intractable social problems. This book places visioneers in the broader tapestry of technological enthusiasm and optimism that has marked much of America's history. Throughout the history of the United States, its citizens displayed a particular flair and fondness for technological utopianism.[36] Part of this stems from the American experience. Early settlers from Europe saw the continent as an unsettled area containing seemingly limitless resources that they could extract and exploit with new technologies. It's no surprise then that twentieth-century visioneers imagined their technologies unfolding in new frontiers—orbiting in outer space, at the nanoscale, off in cyberspace, and so on.

Like the utopian crusaders of the late nineteenth century, modern visioneers wanted to improve society. These modern utopians predicted that technologies they advocated would have a transformative effect on society as humans mastered the ability to create new worlds, undertook atomic-scale engineering, and, if truly successful, overcame their own biological limits. Nonetheless, visioneers and their supporters were not immune to the lures of profit, celebrity, and sensationalism.

The futures depicted by the people in my story did not unfold as they predicted or hoped. Regardless of their reception or indeed their success as judged by today's circumstances, it is important to closely examine the history of these "failed futures." Through them, we see the challenges visioneers faced in conceiving their ideas, trying to implement them, and defending them against critics and rivals. Along the way, they came to terms with what were sometimes partial or even Pyrrhic victories.

Failure, of course, is a subjective term, and visions of the future do not die easily. Moreover, if we study only "successful" technologies, our overall understanding of technology and its history becomes dangerously skewed. Any history of the American automobile that takes into account only the internal combustion engine hides the many other ways cars were powered, not to mention "failed" transportation systems such as trolleys, high-speed rail, or even the much-lampooned flying car. Uncritical acceptance of such a narrative makes cars powered by an internal combustion engines look "natural" when their "success" really was anything but.

One must view the activities of the technology enthusiasts described here in the context of their time, not by the extent of their success so far. These visions of the future were taken seriously by many people *at the time*. A richer historical picture emerges with a more symmetrical appraisal of success and failure. How did the technically possible become a path taken or not taken? Are visioneers' ideas still shaping our conceptions of the future? In this book, we find visioneers as part of a longer chain of technological enthusiasm and optimism that has marked so much of America's history.

This book's main narrative starts around 1972. It is a story that I am writing some forty years later. Yet, in many key ways, 1972 and 2012 seem closer than the passage of four decades might suggest. Today's planetary threats from climate change and overpopulation resemble in many ways existential dangers that *The Limits to Growth* underscored in 1972. Now, as then, economic uncertainties abound as do questions about the abilities and limits of government to address them. And, in the wings, advocates of geoengineering, synthetic biology, fusion energy, cloud computing, and other "emerging technologies" circulate and visioneer their designs for the future. Exploring the activities and ambitions of people such as O'Neill and Drexler adds depth, richness, and nuance to our understanding of today's technological society, how we arrived here, and where we might be going.