8

The Future for Fixing

Taming an Infatuation

The previous chapters have explored the attractions of new technologies conceived as solutions to modern problems. From scientists and engineers to policy-makers, entrepreneurs and wider publics, this seemingly cool and rational conviction has seldom been recognized as being emotionally charged. Yet for each of these relevant social groups, the relationship with technical innovation has been akin to falling in love. New technologies represent irresistible appeals and inspire unquestioning acceptance. Technology's responsiveness to our every immediate need, real or imagined, gains our implicit trust. Only in retrospect may such confidence seem naïve and misguided. Like in a human relationship, modern society and its technologies have become mutually dependent. The analogy suggests that a lasting relationship may require tempering the torrid love affair. Technologies and the solutions they give us are compelling, stimulating, and transformative. But can modern societies avoid the immediate gratifications of technological fixes in favour of stable bonds?

Enduring Faith in Fixes

This book adopts a historical perspective to explore how technological confidence has come to captivate modern society, but the last two chapters track more recent unexpected outcomes that followed enthusiastic adoptions.

Some side effects of major technologies are common knowledge today, but they are seldom investigated beyond their specific cases. For modern publics, technological solutions – particularly those just over the horizon – remain seductive.

There are several interlinked reasons for this continuing popular support: the ongoing promotion of the paradigm by contemporary technological ad venturers, channelling the spirit of interwar technocrats and science fiction fans; innovating companies seeking new consumer markets for novel problem-solving products and promising an updated version of the postwar future; and media communications, both by traditional sources and by grassroots participants in social media, echoing and extending the hopes of those players. The economic power of consumerism drives governments, too, to conflate product innovation with social progress, and often with the assumption that technological change can be triggered and prepared for but not resisted. A more diffuse attraction is curiosity about yet unexplored human ambitions and the complementary motivations provided by fears: looming problems that compel reassuring solutions. In short, contemporary culture remains skewed towards technological optimism by the pressure of powerful social actors and their rhetoric of progress. Wrapped within this cozy worldview, the narrower confidence in technological fixes can nestle unquestioned.

For over a century, a handful of compelling preachers have proselytized this shared faith. As discussed earlier, none of them shaped wide publics but each influenced distinct cohorts: Howard Scott for technocrats and early science fiction readers; Richard Meier for postwar academics and development agencies; Alvin Weinberg for American policy-makers and young engineers. There have been several figureheads since then.

Steve Jobs (1955–2011), for example, promoted Apple Inc. as a channel of technological agency for human solutions. The company had captured two markets missed by the largest computer company of the period, which introduced its IBM Personal Computer (PC) for small businesses in 1981. Apple's first success was as a supplier and inspiration for the embryonic amateur computing movement via the company's Apple I (1976) and Apple II (1977) computers. Along with competitors Commodore and Tandy Radio Shack, the company attracted a generation of American computer experimenters who wrote their own software and sometimes extended their computers with sensors and output devices. The Apple II proved popular not just among computer hobbyists but also in university research labs that traditionally had improvised equipment to conduct experiments rather than buying expensive and preconceived off-the-shelf devices. These "homebrew" creations (some, like the Apple I, emerging from the eponymous Homebrew Computer Club in Silicon Valley from the mid-1970s) fitted their users' individualistic needs and encouraged their builders to conceive them as generic problem-solving devices.[1]

The second audience captured by Apple was composed of creators and artists from non-technical disciplines. The Apple Macintosh computer (1983), adapting elements of a point-and-click graphical user interface (GUI) conceived by engineers at the nearby Xerox Palo Alto Research Center (PARC), was touted as easy-to-use by non-programmers. An early television advertisement soothed:

> It's more sophisticated, yet less complicated; it's more powerful, yet less cumbersome; it can store vast amounts of yesterday or tell you what's in store for tomorrow; it can draw a picture, or it can draw conclusions. It's a personal computer from Apple, and it's as easy to use as this [finger and mouse click]. Macintosh: the computer for the rest of us.[2]

Its buyers included writers empowered by word-processing and desk-top publishing, and graphic artists enthused by mouse-directed painting and graphics software.

These two subcultures – computer experimenters on the one hand and creative non-technologists on the other – briefly co-existed via such products but thereafter diverged. The Apple I computer had required savvy users to add a keyboard, power supply, and video monitor, and to program it in basic – a challenging set of demands for rank novices. By contrast, the Macintosh computer was notoriously "closed," offering no output ports available to hobbyists to interface it with the outside world. Yet, for both subcultures, Apple spawned zealous supporters who identified the corporation with an ideology of personal liberation, conspicuous consumption, and technical progress.[3]

Apple's origins in the Bay Area south of San Francisco were shared with Stanford University and the burgeoning postwar technical culture of Silicon Valley, the collection of companies that has incubated generations of electronics engineers, would-be entrepreneurs, and start-up companies. It was also the home of Richard Meier, who focused on technological approaches to problem-solving. This Californian enclave became the centre of popular technological faith in America. By contrast, MIT, its east coast academic counterpart in championing American innovation, had become more visibly associated with military contracts and corporate technologies. Californian products and spokespersons exported their credo of individual enablement internationally through companies such as Intel, Hewlett Packard, Google, Facebook, eBay, and Uber.[4]

Perhaps because of these associations, the Bay Area has also nurtured another constituency having less obvious ties to technological confidence. Arguably, an important trigger for the exploding popularity of the counterculture of the 1960s was the freedom of speech and civil rights confrontations at the University of California, Berkeley, across the Bay from San Francisco, and the varied cultural options enabled by the pattern of population mobility of the west coast.[5] California generally, and the Haight-Ashbury district of San Francisco in particular, became a mecca for those seeking freer lifestyles and alternatives to "the establishment" – power-holders then identified as government, law-enforcers, and corporations promoting conservative politics, peacetime militarization, and traditional social values supported largely by the older generations. In retrospect, this countercultural opposition appears to be directly antithetical to Alvin Weinberg's technological fixes. As head of a national lab responsible for nuclear energy, Weinberg was then at the peak of his influence, advising presidential committees about technological means of waging war and defusing the likelihood of race riots, and beginning to lecture student audiences on engineering as a social tool.

Nevertheless, the counterculture was a diverse and fluid movement. From it came Stewart Brand (1938–), an eclectic writer who had enduring influence in tracking the shifting flavour of shared technological concerns and enthusiasms. He became best known for *The Whole Earth Catalog*, a periodical that appealed to the individualistic and anti-hierarchical spirit of his generation and that he continued to adapt to new media and audiences over two decades.[6] A patchwork quilt of design ideas, manual skills, inspirational reviews, practical philosophies, and commercially available resources, it collected themes that eventually intersected with the home computer movement and early online communications. His *Catalog* was oriented towards information-sharing and self-sufficiency with an amalgam of do-it-yourself resources. It epitomized a countercultural engagement with independent tinkering. Before there was an internet, Brand and associates promoted the WELL (Whole Earth 'Lectronic Link, 1985), a dial-up bulletin board system allowing users to post and receive public messages and communicate via special-interest groups, amounting to an early implementation of a virtual community.[7] In later publications, Brand increasingly enmeshed his ideas with commercial innovation and new technologies. He linked the east and west coast tech cultures with a journalistic account of the MIT Media Lab, which he identified as emblematic of work by technologists to *invent the future* through technology.[8] Although his *Catalog* had begun with a clear stance against "government, big business, formal education, church," Stewart Brand's activities built bridges with each of these interests. For a time, he advised the governor of California and helped found a business consultancy, the Global Business Network, during the 1980s; his publications referenced academic research, particularly that associated with corporate and consumer interests; and his later environmental writing sought to address metaphysical themes through the demanding eyes of a technological rationalist. With his subtext of empowerment, Brand thus helped to proselytize and broaden technological faith in wider culture – at least west coast American culture.[9]

The Momentum of Confidence

Contemporary technological fixes are also promoted by our cultural attraction to novelty. Consumer culture, first established in North America but increasingly taken up worldwide since the late twentieth century, has been conditioned by new products and has made collective expectations of progress endemic. These cultural confidences have waxed and waned for specific technologies. Space flight, for example, arguably captures less popular enthusiasm today than it did over the preceding century. Interwar science fiction, followed by Cold War rocket programs and the Space Race, caused public fervour to peak with the Apollo missions to the moon, but interest fell with the subsequent Skylab, space shuttle, and international space station programs.

These heroic initiatives were not portrayed to the general public as technological fixes: they did not aim or claim to solve immanent problems with a neat technical solution. However, they were certainly understood as technological fixes by successive American administrations. The earliest upper-atmosphere aircraft and satellites carrying film cameras had been designed to short-circuit a looming political problem: public concerns about a "Missile Gap" with the Soviet Union. These experimental technologies, some unknown to the American public, had the covert purposes of identifying lagging American military progress and inhibiting Soviet dominance. In the same way, the subsequent space race equated technological progress with political ascendency. With the later diplomatic accommodations of nuclear downscaling and rising international cooperation, the promises of the space age began to evaporate.[10]

More mundane contemporary issues nevertheless continue to evoke widespread technological faith and illustrate the enduringly popular appeal of technological novelty. A contemporary version is the promise of the "smart city." Its claims are typical of technological fixes and breathtaking in their aspirations. Smart cities are an open-ended promise, envisaging technologies that will solve the problems of urban life, including traffic, public safety, and social well-being.

Recall **the characteristic attributes of a fix: claims about its simplicity and cleverness; its identification as a straightforward and deliberate technical solution to a social, political, economic, or cultural problem; its punctual focus on an immediate and local issue rather than a consideration of existing systems, social infrastructure, and human constraints; its identification of promised beneficiaries but neglect of potential harms and externalities; its requirement of expert implementation and citizen acceptance.**

The rhetoric of smart cities champions a variety of fixes for identified problems but has been sustained by enthusiasts seeking to implement their favoured technologies. "Smart" is loosely defined but hints at the assumed social benefits of information. The intended benefits are often disturbingly vague. It may mean an innovation that is either economically sustainable, resource-efficient, or responsive to the needs of city-dwellers. A common theme is technology to acquire and report urban conditions for stakeholders, commonly defined as local government, businesses, or mobile citizens. The most frequently discussed genre of solutions is integrated information and communications technologies. Smart cities would add a network of sensing devices, communication links, and control software to new or existing city developments. Integrated systems could predict congestion of roadways, public transport, and even sidewalks and take corrective actions. High-efficiency streetlights could illuminate a pedestrian's path and turn off to save energy after they had passed; mobile devices could display optimal routes for pedestrians and identify nearby conveniences; fine-grained environmental conditions – smog, ultraviolet exposure, and weather – could

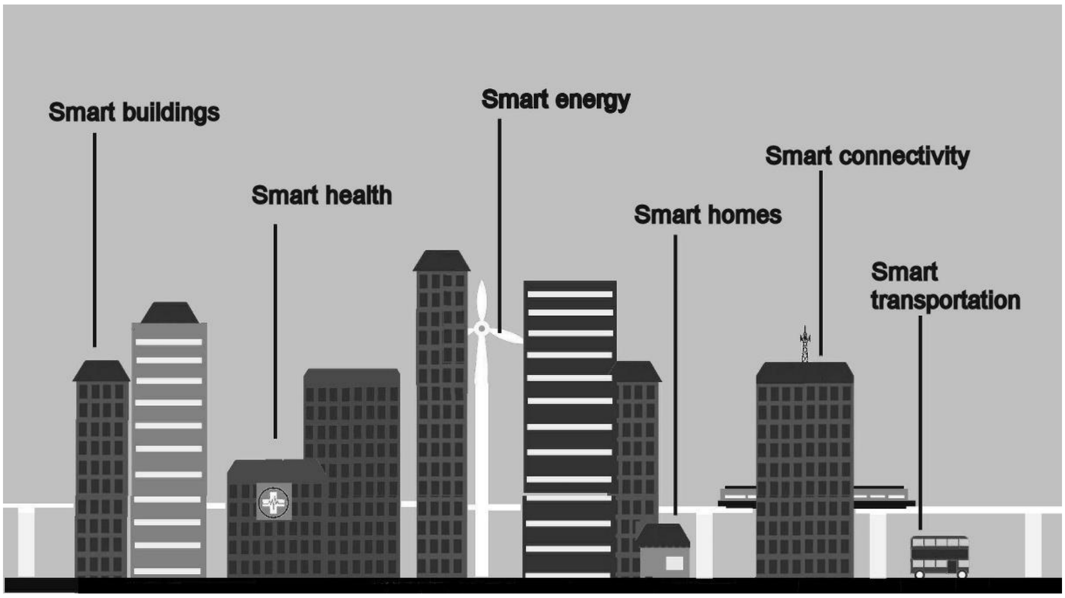

Figure 8.1 Unassailable smart cities: reduced to simplistic rhetoric and imagery, what's not to like?

be reported, and avoided, at street level. The subtext of smart cities, like previous technological fixes, is that their innovations can be implemented with a net saving of human labour and complexity. Cities such as London, for instance, currently employ automatic cameras and ticketing systems to detect drivers entering the city and imposing "congestion charges," a system that aims to avoid multiplying the bureaucracy of traffic police.[11]

Integrating such useful innovations nevertheless relies on optimism about engineering design at the system-scale. Urban environments are sociotechnical ecosystems that evolve under the influence of disorganized forces; a genuinely smart city would have to be adaptable in the same way. More worryingly, the common experience of city management is generally poor. Consider the management of roadworks to locate and replace water and electricity services, in which separate city departments may scarcely be aware of each other's activities. Such interdependent systems, created ad hoc over decades, tend to co-exist and piggy-back rather than being designed to cooperate productively. Of even greater concern is the maintenance of infrastructure. By contrast to some well-maintained cities, interstate rail and freeway networks have declined; bridges built during the 1930s have increasingly failed owing to lack of monitoring, maintenance, and adaptation to traffic requirements, a key requirement of complex systems. At the city scale, unlike at the interstate level, there may be convergence of public attention, government responsiveness, and taxation mechanisms that sustain such visible networks, but these are essential social and political dimensions of the technical systems they sustain. As illustrated by the examples in chapters 6 and 7, human systems have repeatedly had to adapt to support clever fixes that were initially portrayed as wholly technological and straightforward.

Another dimension of concern, as with earlier technological fixes, is the intended beneficiaries. A smart city could be optimized to promote the interests of drivers (e.g., by temporarily opening routes to make pedestrian or cycling traffic easier) or, quite distinctly, could promote the interests of civic government (e.g., identifying and containing disruptive protesters). Such competing interests have long been recognized. The overtly political dimensions of city governance were incorporated in the design of the wide radial arteries of Paris, the low-clearance parkways of New York State, and the wall that divided East and West Berlin, and can be expected to be more readily configurable in smart cities.[12]

In common with other technological fixes, the promises of smart cities rely on enthusiastic promoters. A technology enthusiast who has promoted both space flight and urban solutions – attracting investors and ardent fans in the process – is Elon Musk (1971–). As an entrepreneur and technology promoter, Musk founded Space Exploration Technologies (SpaceX, 2002), an American firm developing space vehicles as a commercial competitor to organizations such as NASA and the European Space Agency. The company's vehicles gained attention for extending technical capabilities (notably vertical soft landings of a space vehicle on land and on a seaborne platform) and earned revenue by transporting payloads for government and commercial customers.

Musk has also been noteworthy as co-founder of the electric car company Tesla Inc. He combined his two largest technology-demonstration projects by launching one of his cars on a SpaceX vehicle in 2018, making them the first two privately funded products to leave Earth's orbit. Via such publicity coups, Musk is a notable proselytizer of technological faith. He has forecast private space flights for eventual settlement on Mars and potentially terraforming it for humans (a more extravagant promise than mere geoengineering of the Earth's climate, described below) and imagines braincomputer interfaces to liberate human capabilities. He has promoted more down-to-earth conceptual solutions to urban problems, including high-speed transportation between cities via a passenger-carrying pod in an evacuated tube (a scheme dubbed the "Hyperloop") and networks of underground tunnels for moving cars and people. Technological solutions, he claims, are generally best, but his hubris raises controversy along with his public profile. The Hyperloop, imagined as a ground-transport replacement or supplement for aircraft, airports, and railways, has been criticized as a sparse technical sketch that ignores complex human systems and their implications.[13]

As detailed in previous chapters, entrepreneurial caution is generally a weak complement to enthusiasm and profit. Elon Musk and other contemporary technology adventurers spearhead popular enthusiasms and merge them with corporate aspirations by stimulating consumer anticipation and investor confidence. Other high-profile investors and advocates with varying degrees of technological hubris include businessman Richard Branson (1950–), CEO of Virgin Galactic; Microsoft co-founder Paul Allen (1953–2018) and executive Charles Simonyi (1948–); Amazon CEO Jeff Bezos (1964–); and Google executives Eric Schmidt (1955–), Ram Shriram (1956–), and Larry Page (1973–). Such speculation about private and corporate exploitation of the solar system threatens another century of unanticipated consequences. There is not yet national legislation to monitor and supervise such activities, a requirement of the Outer Space Treaty agreed between the USA, the UK, and the Soviet Union in 1967, and now subscribed to by 107 countries.[14]

Such visions, whether urban or extraterrestrial, flourish in a context of entrepreneurism and technological enthusiasm. Confidence in technological fixes becomes implicit: technology as a solution to as yet unidentified human problems is tacitly assumed. The rhetoric of progress shared across media by confident evangelists can encourage public acceptance as the default outcome.

Men Like Gods: Imagining Global Repairs

The scale of attention and infectious self-confidence displayed by space entrepreneurs is characteristic of other past and contemporary technological optimists and fixers. When H.G. Wells wrote his utopian novel *Men Like Gods*, he imagined a technological world that espoused collective wisdom without political hierarchy. Unlimited knowledge and liberty – free discussion, free movement, and privacy – combined to create a rational communitarian society.[15] Yet this sensitivity to both social and technological dimensions was unusual. Others have found such clarity of shared purpose either to be an unlikely outcome, on the one hand, or a trivially obvious benefit, on the other.

Social anthropologist Edmund Leach explored similar themes in his Reith Lectures broadcast on BBC radio in 1968, which open with a provocative statement:

> Men have become like gods. Isn't it about time that we understood our divinity? Science offers us total mastery over our environment and over our destiny, yet instead of rejoicing we feel deeply afraid. Why should this be? How might these fears be resolved?

Leach noted that "we love our machines … Technical wizardry is just what makes life worth living, it is the badge of civilisation." He noted that the natural and social sciences revealed regularities and insights, and consequently scientists and technologists could no longer be detached: they had a responsibility to apply their knowledge, while meticulously maintaining their connections with both nature and culture. His explorations were not prescriptive but, rather, suggested that science provided powers that had to be patiently absorbed and cautiously applied – hardly the practices of the modern world.[16]

The same year, Stewart Brand's first *Whole Earth Catalog*, subtitled *Access to Tools*, reduced these musings to a strapline and reoriented it as a motivation for his technological compendium:

> We are as gods and might as well get good at it … A realm of intimate, personal power is developing – power of the individual to conduct his own education, find his own inspiration, shape his own environment, and share his adventure with whoever is interested. Tools that aid this process are sought and promoted in the WHOLE EARTH CATALOG. [17]

The god-like power of adventurous technology was a theme familiar to professional technologists, too, and championed by Brand in his later writing. Moving from periodical editor to technology journalist to business consultant, Stewart Brand increasingly adopted the role of futurist and proselytizer. Founded in 1996, his Long Now Foundation aimed to encourage dialogue about long-term thinking, and his book *Whole Earth Discipline*, written a decade later, provides an early twenty-first-century take on technological fixing into the deep future. The book is unabashedly optimistic about grand technological schemes as the only means of ensuring societal survival in the long term. It mutates his old strapline to "We are as gods and have to get good at it." Brand describes his orientation as "scientific rigor, geoeconomic perspective, and an engineer's bias, which sees everything in terms of solvable design problems," a stance evoking Richard Meier's focus a half-century earlier (chapter 3) but with Alvin Weinberg's looser commitment to detail.[18]

Brand identifies moralistic and rebellious environmentalists as his principal opponents and pragmatic technologists as allies: "Engineers are arriving who see any environmental problem neither as a romantic tragedy nor as a scientific puzzle but simply as something to fix."[19] The most ambitious but urgent of these hubristic fixes, he argues, is geoengineering. The pace of anthropogenic climate change is now so rapid, and so unlikely to be managed by conventional human approaches, that the global climate must be ameliorated "by adjusting the nature of the planet itself through large-scale geoengineering." This is a classic Weinbergian technological fix but one of unprecedented proportions. Understanding the fundamental nature of cli mate change, he suggests, is the wrong focus: we should concentrate instead either on ways of merely controlling the planet's overall temperature or of limiting carbon dioxide emissions, prescribing a kind of global aspirin or antacid remedy instead of adoption of a healthier lifestyle. Alvin Weinberg himself had suggested the much more restrained, but still consequential, technological fix of wholesale adoption of nuclear power to reduce carbon dioxide emissions as a major contribution to climate change.[20]

Ideas for geoengineering fixes have been ingenious but highly contested. Two general options have been proposed: either to concentrate on temperature control by reducing the influx of sunlight or to reduce greenhouse gases, particularly carbon dioxide and methane, which trap solar energy and thus contribute to global temperature rise. Solar radiation could be blocked, for example, by creating a cloudier atmosphere to reflect sunlight away from the earth. Cloud cover could be increased and brightened, for instance, by seeding the atmosphere with sulphur to increase the planetary reflectance (known as albedo enhancement). This is an ironic complement to the unintended pollution of twentieth-century skies by industrial by-products. The sulphur might be distributed via commercial aircraft or shot from cannons, which could produce effects lasting weeks, or seeded in the stratosphere for longer-lasting effects. Alternatively, marine clouds could be increased by unoccupied ocean-going ships, controlled by satellite and powered by the wind, spraying aerosol-sized droplets of seawater (figure 8.2). Still other options for albedo enhancement include growing crops chosen for their high reflectance or painting the roofs of buildings white.[21]

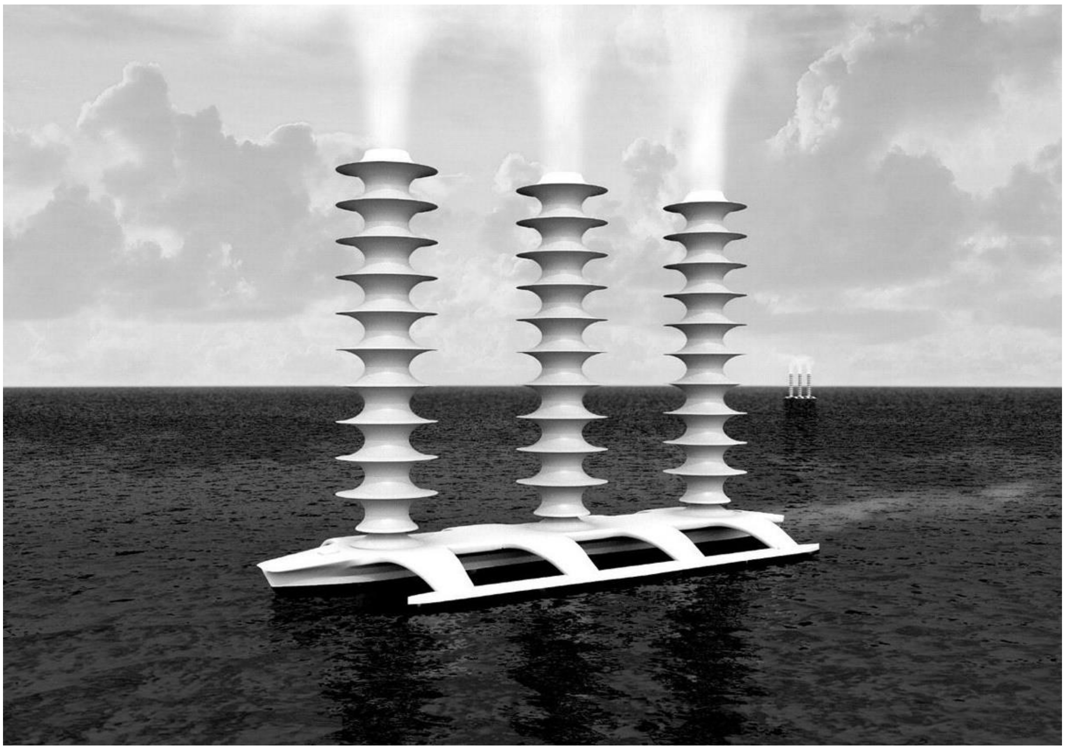

Figure 8.2 Optimistic repairs for the global greenhouse. Salter concept for aerosol-generating ocean vessel to counteract climate change via cloud whitening and planetary cooling. Enthusiast Stewart Brand notes, "the vessel is incredibly cool looking." Salter, Sortino, and Latham, "Sea-Going Hardware for the Cloud Albedo Method"; Brand, *Whole Earth Discipline*, 285.

None of these schemes addresses the continuing rise of carbon dioxide caused by burning petroleum-based fuels, which would carry on making oceans more acidic and harming marine ecosystems. Thus, the other, somewhat deeper, approach to a technological fix for climate change involves con trolling the concentration of greenhouse gases. Here, too, tactics are inventive but uncertain. One controversial approach that has been trialled on a small scale is dumping iron particles to be consumed by microscopic marine species such as phytoplankton. This source of nutrients is intended to fertilize the seas, producing a bloom of algae that also absorb airborne carbon dioxide; when they die, the organisms carry their biologically bound carbon deep enough to decay slowly, keeping it trapped for decades or centuries.[22]

A seemingly more "natural" alternative is large-scale afforestation, planting millions of trees to absorb some or all of the carbon dioxide produced by human activities. A complement to such biological engineering is Carbon Capture and Storage (CCS), a variety of schemes aiming to absorb, concentrate, and dis pose of carbon dioxide. As with other technological fixes, the putative solutions are seldom conceived as elements of sociotechnical systems that would need to be fitted into conventional human practices. Needless to say, each of these fuzzy options carries consequences – scientific, technological, economic, social, ethical, and cultural. New technological systems would have to be implemented within pre-existing systems comprising national laws, cultural practices, public support, and interdependent economies.[23]

Reporting on such ideas, Brand supports their ambition by citing supporters more often than critics and by buttressing his arguments with science fiction stories that imagine terraforming planets for human benefit. Yet geoengineering is qualitatively unlike Alvin Weinberg's proposals for global nuclear power. While he suggested that societies could make a transition to nuclear power generation, Weinberg was able to conceive of some of the profound consequences because they were already familiar on a smaller scale: the need for scaled-up uranium prospecting and refinement; the complementary requirement of replacing petrochemical fuels for vehicles with electricity; the need to replicate this transition in more and less affluent countries; wholesale adoption by populations, with predictable outcomes for those less able to adapt; and, not least, the problem of rapidly accumulating radioactive waste requiring its own fix. By contrast, geoengineering schemes offer experimental solutions on a planetary scale without precedents to guide design choices. Unlike terraforming the barren planets of science fiction, geoengineering would be experimenting with the only home that humans have. It would also magnify the problems of inequity. Some solutions will affect unlucky geographical regions, species, or vulnerable human populations (such as those inhabiting river deltas likely to face unpredictable flooding following climate manipulation). Thus, geoengineering suffers from the faults explored in chapter 7, being intrinsically over-confident, short-sighted, risky, and unjust on a scale that technological fixes have not yet been. Independent of the scheme chosen, the manipulation of the physical and biological system of the biosphere – the largest and most complex machine known, to describe it from the perspective of technological fixers – is inherently dangerous. A Royal Society panel drawn mainly from prominent scientists and engineers not surprisingly focused on the science and engineering rather than on the social and ethical dimensions of geoengineering. The members recommended that, while geoengineering deserved careful modelling, the numerous technical uncertainties made it worth considering only as an option of last resort.[24] The putative solution falls back on Weinberg's original notion of the quick fix: geoengineering is an emergency measure borne of desperation, in which we have no time to evaluate consequences.

It is worth emphasizing that the proponents of geoengineering have seldom analyzed their schemes holistically. The social, political, and economic side effects are usually compartmentalized as externalities. As with other cases of technological fixes there are other human options. These include actions that are already familiar: legislation to limit or prohibit carbon dioxide production from power plants and vehicles; taxation to discourage environmentally harmful activities or commerce; social initiatives to encourage new behaviours; ethical teachings to alter understandings of collective harm and responsibility; dietary changes to scale down the consumption of meat and milk (ruminant digestion being a significant source of methane). Operating more locally and reversibly than planetary engineer ing, these tactics may have advantages in trialling reversible options and could be argued to more faithfully ally science, technology, and society than do bold geoengineering schemes.[25]

But a second optimistic technology urged by Brand is biotechnology, especially via genetic modification. His scenario of looming crisis (in this case, the Malthusian crisis of insufficient food supplies as climate change reduces arable land) argues for quick fixes out of necessity, but he emphasizes the positive appeal of optimistic and daring technological solutions.

Genetic engineering is qualitatively different from geoengineering and less readily categorized as a mere technological fix. It is a scientific field that has progressed over decades of international research. By contrast, geoengineering arguably represents a spectrum of half-baked technologies cobbled together from the worst traditions of engineering repair. Genetic engineering has become positively associated with human health, which often carries the seal of popular approval for new technologies. For example, Dolly the sheep (1996–2003), now stuffed and on display at the National Museum of Scotland in Edinburgh near where she was raised, represented an aspirational use of genetic engineering. Although Dolly was the first mammal cloned from mature body cells, a procedure still deemed abhorrent and internationally prohibited for humans, the longer-term goal was to develop techniques for genetically modifying animals to produce milk as medicine. Sheep or cows, for instance, would be modified by incorporating human genes into their DNA to produce important proteins that are lacking in human victims of genetically inherited illnesses such as cystic fibrosis and haemophilia. The redesigned farm animals, conceived as living pharmaceutical factories, would supply such proteins in their milk to treat what researchers hope eventually to be a long list of genetic illnesses. A growing variety of other experimental cloning techniques could potentially be used to correct genetically inherited diseases or to develop other therapies. Since the 1990s, in fact, most insulin production around the world has converted from the former method – extraction of the hormone from cow and pig pancreases, a reliably sourced by-product of the meat industry – to a spectrum of genetically engineered variants manufactured in pharmaceutical factories. Developed in research contexts that typically receive scrutiny by medical and licensing authorities and wider publics, these current and potential technological fixes have often been viewed as comparable in principle to other, more conventional ones such as radiation therapy for cancer or heart-valve replacement surgery: risky for patients but relatively free of potential societal harms.[26]

Nevertheless, Stewart Brand's promotion of genetic engineering considers a more contentious domain: genetically modified (GM) foods and species to provide resources of wider human utility. In the most urgent form of the argument, GM is touted as a technological fix for chronic food shortages that result from climate change. An even more contentious version suggests its application for creating species better adapted to deteriorating environments (the most dramatic of which is the potential modification of the human species, as discussed below).

Genetically modified foods are a large and growing class of products created by a variety of genetic technologies. The best known and most popular have been foods that solve relatively minor and non-urgent problems of food production, transport, and consumer appeal. An early example was the Flavr Savr tomato, approved by the US Food and Drug Administration (FDA) in 1994. The tomato was genetically engineered to improve transport robustness and shelf-life while retaining a natural colour. The product failed commercially not because of identified environmental dangers or consumer fears but because of conventional side effects: no practical saving in harvesting or transport and unattractive taste. It proved to be an unnecessary solution to a non-existent problem. More broadly, genetic modification of consumer foodstuffs and animal stocks has introduced new technologies requiring careful evaluation but seldom qualitatively distinctive improvements. For this domain and its interest groups, the motivation for quick technological fixes is consequently more difficult to defend.[27]

Other GM foods have been developed to improve agricultural yield with the aim of reducing food costs. Genetically modified maize, for example, can be designed to be drought-resistant (e.g., Monsanto DroughtGard™, licensed by China in 2013) or to contain proteins that are toxic for certain insects. Each GM variant carries distinctive implications. For instance, adoption of herbicide-tolerant genetic varieties is practised in conjunction with higher herbicide spraying, and excessive use of these chemicals carries specific consequences for ecosystems. The most recognized side effect is herbicide resistance, as weeds rapidly evolve to develop tolerance and require ever-greater quantities of more toxic herbicides in an unsustainable cycle. These chemical treatments increase environmental pollution and potentially affect animal species.[28]

Similarly, insect-resistant GM hybrids threaten ecosystems in large-scale plantings. The US Environmental Protection Agency (EPA) consequently imposed regulations to require farmers to plant unmodified maize in nearby areas to prevent eradicating the vulnerable target strains of the insect pests entirely, thereby seeking to delay the inevitable rise of GM maize-resistant varieties. This is a typical example of a traditional human fix to counter a technological side effect: a legal correction to control over-enthusiastic use of the technological solution in order to reduce later negative outcomes. As with seemingly innocuous additives to plastics discovered to have problems decades after their introduction, opponents of GM maize challenge over-optimism and complacency about unsuspected side effects. Among possibilities are sensitivity of other species to the proteins in the maize, an important concern given the ubiquity of maize in animal feed and human food products. Another is so-called "gene flow," in which genes from the hybrid may transfer to other species of crop with yet uninvestigated consequences.

Arguments have been made, however, for technological fixes for food supply to benefit more urgent and needy audiences, notably populations starved of adequate and nutritious food. A stronger case closer to Stewart Brand's theme has been made for "golden rice." Conceived as a genetically modified variety of rice designed to synthesize beta-carotene, golden rice aims to counter the lack of dietary vitamin A for deprived populations, much in the way that vitamin-enriched flour was introduced in North America and Britain during the Second World War to relieve vitamin B deficiency. Golden rice is a classic technological fix that seeks to bypass political, social, and cultural routes via a speedy technical innovation. Vitamin A deficiency is associated with inadequate dietary variety and has been treated by aid agencies via high-concentration oral supplements or injections. The pro - mise by promoters of golden rice is that it will supply a simpler, wholly technical solution to chronic malnutrition, even though it requires an amount of production, distribution, and monitoring comparable to that of earlier supplements. Critics argue that the golden rice solution also avoids addressing deeper socio-economic reasons for poor nutrition and, consequently, defuses action to remedy more pervasive faults in human systems. They note that it threatens grassroots solutions such as cooperative cultivation and distribution of conventional dietary sources of vitamin A such as sweet potatoes, fruit, and leafy vegetables. As with the cases explored in chapter 6, proponents have tended to overlook the traditional social and economic supports needed to make golden rice and other dietary supplements viable: a network of manufacturing, distribution, and, not least, external funding and research to make this stop-gap fix more sustainable. Opponents criticize the potential for the consequent dependence of poor countries on corporate products supplied for profit. In response, proponents have suggested that (with government funding or corporate largesse) golden rice could be made available for free to subsistence farmers, and free licences could be offered to developing countries, a plan that is nevertheless likely to consolidate the status of disempowered populations and countries. There are also purely technical issues with golden rice: current varieties, none yet manufactured commercially, supply insufficient dietary vitamin A for adequate health, and it is unclear whether cultivation and consumption could become wide - spread. Stewart Brand has characterized "anti-genetic engineering environmentalists" attempting to "frighten African nations" as responsible for the difficulties in promoting golden rice and cites the lack of identified health problems as sufficient evidence to justify its rapid uptake.[29]

Wider arguments against genetic modification as a routine category of technological fix centre on the issues of complexity and risk. Biological and ecological systems are more sophisticated than human-designed systems, and, consequently, genetically modified organisms should be expected to evince unanticipated outcomes more frequently or dramatically than human made technologies. This is a familiar source of problems in large systems and calls for meticulous attention at the design stage. The concerns about risk vary across the type of genetic engineering considered. For example, those that are contained – such as animal cloning and gm hormone production in factory environments – present less environmental risk than does the propagation of GM crops or gm insects in the open environment, where they may potentially interact with other species in unpredictable ways. And unlike human engineering of hardware and software, some biotechnologies can self-propagate and evolve in their new environments, resisting containment and control.[30]

Critics cite the "precautionary principle" as a social and ethical brake on innovation for such engineering systems that can rapidly produce unpredictable effects. It calls on decision makers to establish that a change will be safe before it is implemented. This is the complement of typical legislative regulation, which bans (some) products proven to be harmful. Although there is a regulatory system to assess food and drug safety, such policy mechanisms attend to a relatively narrow range of potential harms. The term entered usage in the 1980s and since then has become common in environmental dialogue, particularly in relation to adverse effects from gm technologies. The principle critically connects innovation, benefit, and risk, expressing broad sensitivities that were uncommon during the twentieth century and that remain largely outside legal frameworks today.[31]

Both geoengineering and non-medical genetic engineering, emphasizing the technological and scientific dimensions of these subjects, have encouraged public deference to their experts as reliable social and cultural guides. A prominent lay representative for this contemporary hubris, Stewart Brand argues that this is appropriate: "environmentalists do worst when they get nervous about where science leads, as they did with genetic engineering." His implication is that science and technology provide the tools for expressing human ideals and should not be constrained or redirected by cultural values, political philosophy, or ethics. Indeed, he suggests that rational decision making must be purely scientific and that science should be depoliticized and utilitarian. Thus, governments should refrain, for example, from adopting policies too hastily about banning plastic bags or rejecting nuclear power because their benefits versus harms can be assessed scientifically, unambiguously, and unromantically. Brand's words echo Howard Scott and the interwar Technocrats: "Instead of yelling 'Stop!,' engineers figure out what the problem is, and then make it go away. They don't have to argue about what is wrong; they show what is right."[32]

More Than Human: Technological Fixes for Our Species

This seat-of-the-pants forecasting plays to our collective optimisms about technological possibilities. Brand suggests that human achievements will outpace our problems:

> How about, say, two hundred years from now? If we and our technology prosper, humanity by then will be unimaginably capable compared to now, with far more interesting things to worry about than some easily detected and treated stray radioactivity somewhere in the landscape … Extrapolate to two thousand years, ten thousand years. The problem doesn't get worse over time, it vanishes over time.[33]

This long-term perspective seems to distinguish it from the typical short-term and short-sighted technological quick fix. It expresses the frontier ethic and science fiction optimism of constant expansion. Humans are the most creative of species, it argues; space travel and colonization of new worlds is merely a continuation of our zeal to discover, conquer, and expand. Exploration and colonization of new worlds is human nature, as is outgrowing old environments. According to this perspective, sustainability is less important than curiosity-seeking and innovation. It hints that the journey, not the ultimate destination, is what matters, and imperfect technological fixes along the way are part of the trip, to be experienced but ultimately left behind.

Yet this complacent long-term vision can be decomposed into numerous individual fixes adopted unreflectively, each with worthy aspirations but shallow short-term attentions. Instead of focusing on immediate social, political, or cultural issues, it urges technological improvements to satisfy distant hopes and dreams for entire nations, for the planet, or even for the human species. Such grand and hazy goals, as suggested by the case of geoengineering, nevertheless carry numerous awkward details that may tend to accumulate, rather than vanish, over time. At risk is intergenerational justice: storing up a legacy for future generations to sort out. But Brand's optimism argues that, from a distance, human progress through technology looks rosy and obvious; his opponents might counter that, averaged over the past century, new technologies have implanted systemic problems having slow gestations and still unexplored consequences.

In the early twenty-first century, the most emblematic of these grand ambitions has attracted various labels, notably "transhumanism." The term was coined as early as 1957 by Julian Huxley (1887–1975) – biologist, first director of UNESCO, and brother of novelist Aldous Huxley. He used it interchangeably with "scientific humanism" to describe the imperative created by "new knowledge amassed in the last hundred years" that has "defined man's responsibility and destiny – to be an agent for the rest of the world in the job of realizing its inherent potentialities as fully as possible." As with proponents of technological fixes, Huxley saw this as a task for a cadre of techno-scientific elites, "a few of us human beings … appointed managing director of the biggest business of all, the business of evolution."[34] At the heart of the modern expression of transhumanism is the enthusiastic identification of new technologies as dramatic means of altering human capacities. The idea of liberating or unlocking greater "humanness" via technologies is an ironic twist. Transhumanism taps into aspirations for personal health and happiness, the most optimistic and widely accepted domain of technological fixes. Yet it carries the potential not merely of fixes for personal health but also more ethically suspect extensions: the goal of achieving technologically enhanced communities via genetic engineering, bio-technical alterations, or retrofitting.[35]

This technological enhancement, proponents argue, will be transcendent, liberating individuals and empowering collective human progress at an un precedented pace. Academic philosopher Steve Fuller has labelled the theme of re-engineering our species "Humanity 2.0" and argues that new technological capabilities will inevitably alter our collective notions of what it means to be human. In effect, technological innovations will supersede or revamp religion, philosophy, and human traditions. This driving of human capabilities by technological agents is the technological fix writ large, with the most competent experts as directors.[36]

The notions of transhumanism did not develop *de novo* but drew on the rising technological faith of the twentieth century. After the Second World War, medical interventions became dramatically more powerful. Cardiac surgery repaired and replumbed the heart and arteries, and experimental heart transplants began two decades later. Replacement of body parts – beginning with corneal transplants from cadavers and kidney transplants between identical twins – became routine, and failing organs were supplemented or replaced: by the 1960s, heart-lung machines during cardiac surgery, dialysis machines for periodic treatments of chronic kidney disease, and wearable heart pacemakers were widely employed.

Surgical alterations also became feasible and increasingly available after the war. Plastic surgery repaired not only injured or congenitally malformed features but also enabled cosmetic enhancements as elective surgery. It is notable that these new powers faced contemporary criticism but gradually became culturally acceptable. Facelifts, breast enhancement, and hair trans plants rose in popularity first in southern California (aided by the economic motivation of employment in the entertainment industries) and later in other regions. More recently, consumer technologies of body modification have abounded: liposuction and implants, bariatric surgery, skin abrasion, Botox injections, teeth whitening procedures, and muscle stimulators. These possibilities have revolutionized long human traditions of adopting prosthetic aids such as artificial legs, dentures, and hairpieces, moving them from external functional or cosmetic additions to permanent elective choices now associated with personal expression and lifestyle. Surely, argue proponents of transhumanism, these powers to improve humans will continue to expand indefinitely.[37]

The theme is hardly new. These new bodily options, rapidly identified as commodities for affluent middle-class consumers, inherited on a personal scale the hopes and dreams of science fiction for humanity as a whole. Similar zeal for improving human physiology and intellect had been explored in the golden age of science fiction through the mid-twentieth century. Isaac Asimov's *I, Robot* series of novels imagined how robots could extend human power while remaining dedicated to human needs; Arthur C. Clark's screen play for *2001: A Space Odyssey* depicted evolutionary development from apes to super-human intelligences tightly coupled to technological powers. As explored in chapter 5, science fiction and popular technological forecasts later converged. A 1965 *Our New Age* Sunday comic strip by Athelstan Spilhaus promised: "By 2016, man's intelligence and intellect will be able to be increased by drugs and linking human brains directly to computers!"[38]

The theme of intellectually superior intelligences moved more assuredly from science fiction to forecasting with the writings of Vernor Vinge (1944–), an academic computer scientist and science fiction writer. In 1993 he suggested that the rapid progress in computing would lead to a point in the foreseeable future that he labelled the "technological singularity." After this point, forecast by proponents as sometime during the present century, human intellectual capabilities would be superseded by artificial intelligence (AI), threatening to leave humans increasingly far behind. This pessimistic view about being replaced by artificial intelligences is sometimes called "posthumanism." Inventor and entrepreneur Ray Kurzweil argues instead that human and artificial intelligence could merge, inducting an epoch of exponentially increasing abilities and transcendence beyond biological limitations. Kurzweil, in fact, had a track record in inventing devices that could be seen both as contemporary technological fixes and as illustrations of the transhumanist route, commercializing some of the first text-to-speech synthesizers, print-to-speech reading machines for the blind, and commercial speech recognition software. Critics have argued that predictions of super intelligences are as simplistic as the fantasies of the previous generation, which foresaw domed cities and space colonies around the corner: many of the technological forecasts could be pursued with enough resources and collective will, but few of the forecasters attempted to explore how society would co-evolve with them. Neglecting how complex sociotechnical systems are likely to adapt to technological perturbations is a common failing of naïve forecasting and futurism.[39]

For non-optimists, the singularity seems to represent the worst outcome of technological fixes: the dramatically unpredictable and uncontrollable consequence of short-sighted technological innovations. The transhumanist vision displays a hubristic faith in technology as the means of human transcendence, but it is peculiarly myopic about how human societies and individuals would be involved.[40] For technological optimists, however, the progress towards transhumanism can be charted by contemporary achievements and near-term developments. Among the best-case examples of transformative technologies are electronics and computing, which have improved exponentially in memory capacity and computational speed in recent decades. First identified in 1965 by Gordon Moore, then research and development director of Fairchild Semiconductors and later head of Intel Corporation, the density of transistors on integrated circuits was roughly doubling every couple of years. This empirical technological improvement has been christened "Moore's law," with proponents like Kurzweil suggesting that it is indicative of a wider acceleration of human progress. The promise is not acknowledged by all. Critics note that the historical trend of improvement in computing hardware is slowing and is ultimately limited by physics; that some of the continuing improvements have been driven by narrow technical criteria and industry goal-setting rather than more rapid innovation; and that software tends to bloat and slow computation in the opposite way, and so generates a much more limited net social gain.[41]

A futurist and writer with a longer track record in predicting social effects of technology was Alvin Toffler (1929–2016). As a White House correspondent during the late 1950s and scenario writer for IBM, Xerox, and AT&T during the 1960s, he gained familiarity with the practices of American business, government, and technology firms. His 1970 book *Future Shock* captured growing public concerns about the pace of technological change (much as the Technocrats had done during the Great Depression), and his subsequent book *The Third Wave* a decade later focused on his forecasts at the beginning of the "Information Age." Toffler was a technological determinist, seeing new technologies as causing overwhelming disruptions for which social adaptation was the solution. His ideas about "anticipatory democracy" influenced politicians across party lines, including Democrat Al Gore (1948–) and Republican Newt Gingrich (1943–). Toffler's vision permeated the Congressional Clearing House on the Future created in 1976 and later co-chaired by Gore and Gingrich. Toffler's 1995 sequel to *The Third Wave* included an effusive foreword by Gingrich, then speaker of the House of Representatives; and, as vice-president during the Clinton administration from 1993to 2001, Gore championed government action to adapt US society to the internet. Toffler's ideas were also received positively by the Chinese government from the 1980s.[42]

Yet predicting the future is notoriously inaccurate, and the economic drivers of innovation further complicate forecasting. In a cultural environment primed to expect progress, company investment and academic careers increasingly depend on promises of transformative technologies as much as on actual results. This bias, portraying potential progress while ignoring wider outcomes, reinforces the culture of technological fixes.

The case of nanotechnology, a forthcoming field according to some transhumanists, illustrates the prevailing hyperbole of unrealistic optimism, pop ular faith, and solutions-in-search-of-a-problem.[43] The field was promoted in part by discovery of a new class of molecules resembling the geodesic domes popularized by Buckminster Fuller and, consequently, named "fullerenes." Investigating these materials opened new directions for scientific research and engineering at the molecular level, or nanoscale. The term "nanotechnology" is consequently a catch-all and has described imagined science fiction scenarios of micro-machines assembled on the atomic scale to reproduce themselves or merely new formulations of powders (such as fullerenes) applied to new problems. Nanomaterials have been touted by rebranded divisions of pharmaceutical companies, the materials industry, and semiconductor firms. Hundreds of start-up firms, funded by industry speculators, have proposed applications such as tissue engineering and regenerative medicine, more readily absorbed drug therapies, and carbon nanotubes instead of silicon for microelectronic devices. A Royal Society of Chemistry publication identified the potential for over 120 diverse applications of the foreseeable future, ranging from medicine to environmental remediation, and to materials that improve on nature. Transhumanists are even more optimistic, arguing that technology integration at the nanoscale is a key element for the improved human of the future. Enhancements might include nanobots providing therapies cell by cell; nanoparticle-strengthened implants to replace or strengthen bone; molecular-scale biosensors to detect and regulate body systems. "Bionics" (biological electronics) might improve human hearing and vision or supplement strength with artificial muscles, as imagined in the television series *The Six Million Dollar Man*. Even more importantly, proponents of nanotechnology hope that eventually it will allow the interconnection of brains to electronics, a development that might allow boosting, re-engineering, or even replacing neuron-based intelligence.[44]

Such bold claims of miniaturizing and revolutionizing all current technological competences launched an unassailable wave of unrealistic optimism. As with the enthusiastic corporate and cultural adoption of plastics a half-century earlier, the wholesale application of nanotechnology makes unanticipated outcomes likely and the precautionary principle relevant.

Figure 8.3 Previewing the future at a conference covering "Biomedical Engineering, Medicine and Pharmaceuticals, Life Sciences, Cardiology, Cancer … and Nano Cosmetics."

is the essence of their aims: technology would be transformed from an efficient fix for traditional human problem-solving into the basis for an endlessly improvable human existence. The vision transcends even popular science fiction scenarios. The *Star Trek* vision of enlightened humans wisely managing their futuristic technologies is replaced by dreams of enhancement, which bypass outmoded cultures and technical limitations and disregard moral convictions.[47]

The transhumanist perspective, not merely placing technology at the centre of modern society but also identifying it as the basis for redesigning humanity, echoes earlier analogs. Previous chapters chronicle the confidence and enthusiasm of technology promoters through the twentieth century as providers of well-being, while noting that many of their inventions had belatedly negative societal effects. The proselytizers among the technological fixers – notably the American Technocrats and Alvin Weinberg – argued for the power of planned technical innovations to directly address or detour around human problems. By contrast, transhumanism takes a different tack between technology, society, and human values. Its attitude exaggerates twentieth-century confidences. Hubristic and self-defining, it identifies technological powers as deterministic and dedicates little attention to the social consequences of enhanced humans in wider society. Transhumanism at tempts to argue that human problems, at least for the privileged cohort of adopters, will evaporate as new technological powers sweep forward. A more direct intellectual genealogy can be traced to eugenics; indeed, Julian Huxley, the first to define the aims of transhumanism, was a leader of the eugenics movement and president of the British Eugenics Society between 1959 and 1962. Emerging in the 1880s, eugenics argued that the human species could be improved by scientifically managing human reproduction. Supporters of eugenics did not seek to enhance humanity beyond a presumed God given limit, but they sought to prevent the dilution of these "superior" traits by "inferior" inherited characteristics. The pseudoscience became popular across the political spectrum at the turn of the twentieth century and in countries across Europe, Asia, and the Americas. In 1915, for instance, the Panama-Pacific International Exposition in San Francisco included exhibits on eugenics supporting its theme of the advancement of civilization.[48]

Organizations and governments implemented bureaucracies based on eugenic policies. The technical details of intentional selection of suitable parents varied from country to country through the interwar period and beyond. Immigration criteria for the United States were designed to filter particular countries and ethnic groups. A combination of legislation, public health administration, and popular attitudes in several countries caused individuals judged to be mentally deficient or mentally ill to be sterilized. More widely still, individuals with physical disabilities or inherited diseases such as deafness were discouraged from marrying. In each country, public opinion largely supported and deferred to expert views.[49]

The social side effects of eugenics hint at more exaggerated consequences for transhumanism, which seeks to create superior humans but via unspecified selection processes. Neoliberals might suggest that the lucky beneficiaries should gain their privileged access to body form and intelligence via the mechanisms of market supply and demand, and draw upon their rapidly rising purchasing power; progressive transhumanists might suggest that governments would ensure their citizens' rights to enhancement; more nationalistic regimes might identify such enhancement as crucial to international competitiveness. In any case, there would be disparity between haves and have-nots. This would be temporary at best and certain to worsen di visions between affluent and poor countries, or technology-privileged and technology-deprived populations. A more fundamental issue first faced by eugenicists, though, was determining superior and inferior traits. Their definitions tended to be circular and to be blind to social presumptions: the "fittest" were those in the upper echelons of society because their privileged social positions reflected their "superior" breeding. In a similar way, transhumanists may tend to favour like-minded (and like-bodied) individuals, introducing a selection bias and consequent social inequalities. In an imagined future world with powerful genetic engineering technologies, infirmities might be prevented or corrected, leading to a more uniformly able and perhaps widely agreed "superior" population but exacerbating the "inferior" status of those unlucky enough to be deprived of it. Warnings about this morally problematic brave new world ushered in by technological faith is not novel, having been raised in 1932 by Julian Huxley's brother, Aldous.[50]

Such sought technological powers exaggerate the problems of technological fixes discussed in chapter 7. Techno-fixers, eugenicists, and transhumanists adopt narrow perspectives: identifying particular problems, focusing on distinct time scales, and attending to specific audiences. They consistently fail to recognize the entwined human systems through which society operates. Instead, they may trade off social cohesiveness for outcomes favouring other parameters. Experts, generally identified as technological enthusiasts, are judged unproblematically to be the appropriate implementers, adopters, and managers of their schemes, thus short-circuiting democratic participation. It is not difficult to appreciate that this privileged perspective systematically disfavours other human contexts and non-human environments.

Imagined Intentional Futures: Irresponsible Innovation or Redirected Ambitions?

The promises and proselytizers explored in this chapter reveal the ongoing conviction of technological faith in modern society. Retaining a historical perspective, it is reasonable to trace the exploration and critiques of alternative paradigms. Can more responsible innovation replace over-confident steps in the dark when considering new technologies? Cautious technological innovation has not been popular over the past century. The widely expressed concerns voiced during the Victorian era about the effects of industrialization became less frequent in the Machine Age. However, as explored in chapter 6, some technological choices were recognized belatedly as blunders and prompted more general critiques and alternatives. These analyses argued that adoption of new technologies tended to overlook social and environmental considerations at the design change, neglected negative outcomes, and often overtly traded off side effects in favour of economic interests.

In a culture increasingly attentive to local and measurable improvements, longer-term inadequacies were less noticed. Such short-termism has been attacked, for example, by political scientist Steven Teles, who describes US social policy as a "kludgeocracy." He suggests that policy-makers generally opt for imperfect fixes rather than for fundamental reforms.[51] His neologism has a technological origin, coming from the computing term "kludge," a cobbled-together fudge of software fixes that gets around an immediate problem but more often than not makes the software more difficult to maintain. The growing usage of his term suggests how far technological methods have infiltrated traditional social and political approaches, and how problematic they are. The technique was at the heart of Alvin Weinberg's proposal of technological fixes for government policy-making.

On a broader and more positive scale, analysts outside "the establishment" have critiqued its growing reliance on technological solutions and offered long-term alternatives. Among the most important have been environmental and political philosophers Arne Naess, Murray Bookchin, and Ernst Schumacher.[52] As introduced in chapter 7, Naess discussed two broad configurations of environmental consciousness: the concerns of what he identified as "shallow ecology" and "deep ecology," respectively. His tracing of shallow thinking maps onto the solutions favoured by supporters of engineering fixes. This ad hoc approach remains the most popular engagement with environmental problems and, as might be expected, has collected a random assortment of ready fixes and adopters. Stewart Brand has vaunted so-called "Bright Green" tactics to address environmental problems case by case. Coined by writer Alex Steffen in 2003, the approach asserts that innovative technologies provide the keys to environmental sustainability, provided that political and economic accommodations encourage them.[53]

Naess identified this technology-oriented approach as inherently misguided. Energy-saving appliances, on the one hand, are a great improvement over the wasteful devices of past decades. Yet they may, on the other hand, encourage consumers to continue to buy, and eventually discard and recycle, even more such "labour-saving devices"; we may ask whose labour is being saved. Similarly, the installation of "eco-friendly" light bulbs, or participation in Earth Day events, may encourage individuals to feel that they are positively contributing to sustainability while leaving the preponderance of their lifestyle unquestioned and intact. Naess proposed his "deep ecology" as a more principled and holistic perspective. Technologies, he argued, are as likely to create negative as positive effects, and so the choice of technology must consider its social, cultural, and economic ramifications.[54]

Murray Bookchin challenged these sensitivities and solutions, arguing that Naess's approach identified the appropriate cultural currents but re quired a more consistent approach that fundamentally reconceived society. Both, nevertheless, had similar criticisms of technology. Some deleterious environmental aspects of technology, they argued, relate to how problems and solutions are framed and addressed: typically, affluent present-day populations are favoured, and other interests are neglected. More pointedly, Naess and Bookchin criticized technological fixes as dangerously seductive: employing technology as a shortcut to bypass deeper social corrections, they noted, makes societal inequities that much harder to eradicate.

Their critiques and solutions map neatly onto the ideas of their contemporary, Ernst Schumacher. A British economist who spent most of his career as economic advisor to the country's National Coal Board, Schumacher spent a period in Burma, an experience that had suggested to him that the distinctive values of human lifestyles could not be reduced to modern Western criteria. His use of the phrase "Buddhist economics" highlighted his view that quality of life in modern societies required a more holistic and spiritual sense of fulfilment. Schumacher's influential book *Small Is Beautiful* argued for this broader perspective on social, environmental, and economic issues. As suggested by the title, he presented the case for rescaling human activities to better serve human and environmental needs. Both modern economics and technological development, he argued, need to be recast. Schumacher identified two flawed models of technology: "the super-technology of the rich," on the one hand, and "the primitive technology of bygone ages, but at the same time much simpler, cheaper and freer," on the other. The first was appealing but also wasteful and poorly distributed. The second was back-breaking and inefficient but readily available. Drawing on the work of Mohandas Gandhi, he defined "intermediate technology" between these two extremes:

> The technology of production by the masses, making use of the best of modern knowledge and experience, is conducive to decentralisation, compatible with the laws of ecology, gentle in its use of scarce resources, and designed to serve the human person instead of making him the servant of machines … One can also call it self-help technology, or democratic or people's technology – a technology to which everybody can gain admittance and which is not reserved to those already rich and powerful.[55]

His perspective mirrored views growing in the counterculture and provided a coherent alternative view of how morally defensible technologies should be conceived and valued. Intermediate in cost, complexity, and sophistication, they would rely on people of intermediate know-how and might consequently trade off these attributes by being of intermediate usefulness rather than high-tech. Schumacher identified key attributes as small scale, small harm, mixed technologies, and design adapted to local circumstances. Examples would include small wind generators like those used on American farms between the wars, which could be repaired or even built from scratch from readily available materials such as wood and wire or equivalent power sources harnessing flowing streams.[56]

The characteristics of appropriate technology, as defined by Schumacher and others, argue that it is adapted to the needs, skills, and resources of its users and environments, and tends to emphasize local autonomy, egalitarianism, and sustainability. A technology ideally adapted to its environment is one that relies on locally available materials and human resources for its design, manufacture, operation, and maintenance. The design is required to be environmentally neutral not just for its users but holistically for all affected parties. These characteristics, he suggested, can serve as goals for guiding wise technological choices.

First, appropriate technologies support local autonomy and self-sufficiency by encouraging local expertise in design, production, and repair. By avoiding reliance on centralized skills and authority, they consequently reduce hierarchies and potential injustices.

Second, such a locally oriented scale encourages responsive and wise innovation. This connection between designers and users crucially distinguishes appropriate technology from Weinberg's notion of the technological fix. Operating on a small scale may make designers of appropriate technologies, who are likely to be the users themselves, more alert to genuine needs and contexts, and to immediate side effects.

Third, appropriate technologies encourage diversity, identified by both Naess and Bookchin as an abstract but valuable principle to be promoted. The concept grows from the scientific principle identified by earlier ecologists such as Aldo Leopold: species diversity tends to produce more resilient ecosystems that can adapt to unexpected perturbations. The idea is also compatible with the notion of technological momentum, which argues that the ferment of nascent technologies offers more adaptiveness to social needs than do mature, large-scale technological systems. There is, though, a counterargument against appropriate technologies: by adapting to suit local context, they are unlikely to benefit from economies of scale and so may prove more expensive to develop and more difficult to maintain consistently.

Fourth, appropriate technologies are likely to be more sustainable in re source usage. By seeking to employ locally sourced materials, they encourage clever innovation and adaptation to suit local contexts.

This principle of having a closed loop system involving production, consumption, and recycling was first identified as a basis for maintaining sound ecosystems by Aldo Leopold and is the basis of lifecycle assessment discussed in chapter 6. Some of these design considerations are summarized in Table 8.1.

Table 8.1 Design considerations informed by critiques of technological fixes

1) Are there implicit assumptions at play? E.g.:

> a) Simplistic identification of the problem (trust in reductionism)
>
> b) Ease of implementation (unsophisticated planning)
>
> c) Confidence in likely success (belief in inevitable progress)

2) Are there identifiable interests ("stakeholders") with distinct views or sensitivities regarding the technology? E.g. particular:

> a) Social groups
>
> b) Species and ecosystems
>
> c) Natural environments

3) Can the technology under consideration be understood as part of a sociotechnical system? E.g.:

> a) How are manufacture, usage, and recovery linked to other technologies and human systems?
>
> b) How is the technology linked to existing activities and interests of relevant social groups?
>
> c) How is it linked to wider environments?

4) Could the technological choice have foreseeable side effects? E.g.:

> a) Technological effects on other parts of the system
>
> b) Social or cultural implications
>
> c) Environmental implications

5) Could the technology be implemented cautiously? E.g.:

> a) Could it be made sensitive to different stakeholders?
>
> b) Could outcomes be monitored adequately?
>
> c) Would it permit corrections or reversals if necessary?

Slippery Vocabulary and Misleading Practices

The rhetoric of novelty, exploiting neologisms like "technocracy," "smart cities," and "transhumanism," has been influential in shaping cultural acceptance of technological fixes. By contrast, the term "appropriate technology" has declined in usage since its peak in the early 1980s. It became increasingly associated with the perceived focus of Ernst Schumacher and Richard Meier: less-developed countries. The concept's relevance and implications for modern urban life were difficult to communicate to professional engineers and wider publics in the developed world. Labels and meanings consequentially have mutated. The term "sustainable technology" has grown in popularity since the 1990s to challenge it.[57] The word has been adopted by companies and policy-makers as often as by grassroots environmentalists, sometimes employed as a form of "greenwash" to label restricted examples of "sustainability," as discussed in chapter 6. The transition from "appropriate" to "sustainable" arguably diluted the ethical demands of wise design.

A term seeking to recover part of Schumacher's wider social and moral sense of appropriate technology, however, is "responsible innovation." The label has been used since the 1960s but has been adopted more recently for inter-governmental planning of research policy and implementation, particularly in Europe. A 2013 European Union report, *Responsible Research and Innovation (RRI)*, describes responsible innovation as

> The comprehensive approach of proceeding in research and innovation in ways that allow all stakeholders that are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to them and (B) to effectively evaluate both outcomes and options in terms of societal needs and moral values and (C) to use these considerations (under A and B) as functional requirements for design and development of new research, products and services.[58]

Such definitions appear to place responsibility in the hands of designers and funders (particularly government funders), with no overt mechanisms for public participation. This direction by technical elites echoes the ideas of the Technical Alliance a century ago and of Alvin Weinberg fifty years later.

The ethical norms and responsibilities are also ill-defined. Seeking grounds for negotiation and consensus, the same report suggests that "Standards on RRI that can be adopted *voluntarily* … *could* include … a shared definition of RRI, including principles *like* orientation towards … gender equality, open access, public engagement *etc*."[59]

By contrast, Schumacher's focus was on designers, maintainers, and communities, and an important feature was the avoidance of hierarchies of power and governance. Central direction of technological design and choice, he suggested, tends to impose solutions that are not well adapted to local circumstances or to weaker parties. A key difference between "responsible innovation" and "appropriate technology," then, is their respective sensitivity to "softer" human concerns. Appropriate technology may sometimes promote cultural and social traditions rather than business growth, for example; responsible innovation, on the other hand, may more often favour the greater good over regional concerns.

Broad adoption of something like the perspectives of appropriate technologies or responsible innovation may appear unlikely. The promotion of deliberate technological futures by ardent proponents, coupled with our collective appetite for novelty and personal benefit, works against more cautious and systematic consideration. As suggested by contemporary futurology, deeper thinking about sociotechnical systems remains uncommon. Among the key aspects identified in the historical cases examined in this book are the under-appreciated frequency – even regularity – of unintended consequences; the poverty of adequate design consideration of such side effects; and, the inherently political dimensions of technological choice. For a century, the trend in technological fixes and consequent side effects has been their scaling up, thereby increasing the vulnerability of regional and even global environments. The interdisciplinary teams studying anthropogenic climate change label it a "wicked problem," in the sense of not being amenable to solution by a single discipline or approach.[60] This growing consensus surrounding the human problems associated with climate change suggests that technological fixes, when they work at all, address problems only at relatively modest scale and in the short term.

As I have sought to show, the history and momentum of technological faith is unsettling. On the one hand, modern culture has become primed to expect and welcome new technological solutions and to disregard critical assessment until they have been widely adopted and found wanting. On the other hand, local incidents have made publics painfully aware of unplanned side effects of specific technologies.

The most consistent thread through this century-long history of technological hubris is the enduring role of rhetoric. Verbal persuasion and imagery have been tools to legitimize optimistic expectations that rely on inadequate evidence or extravagant claims. As the technocrats employed them, speeches in the form of simple tales won over audiences. Early science fiction and popular science magazines portrayed escapist adventures and uncritical futures provided by sage designers. Weinberg's essays and speeches introduced similarly evocative (and evasive) examples. Contemporary entrepreneurs and technological adventurers carry on the tradition. Just as importantly, graphic illustrations have reiterated the rhetoric of technological solutions for our social world, from the technocratic postcards to lurid covers of *Popular Mechanix*, to mid-century corporate advertising and contemporary online media promoting nanotechnology, smart cities, and geoengineering quests. Recognizing the potency of such imagery, I have anticipated reader predilections by avoiding pictures of side effects (e.g., waste dumps or sea life strangled by plastic), likely to be interpreted as partisan or polemical, in favour of the unrealistic promises of positive human futures. My aim has nevertheless been to communicate the faith-like nature of such technological assurances: the brief parables, sermons, and catechisms on which they were based; the modern zealots proselytizing the planned utopian future; evangelists for miraculous technological cures; and the liturgies of modern public discourse. At the heart of the analogy is the nature of faith itself: the quality of unreasoning trust detached from understanding or justification. The irony is that the history of this technological belief has been so poorly supported by rational underpinnings.

NOTES TO CHAPTER EIGHT

1 Wozniak and Smith, *I, Woz*.

2 Apple Corp., "Advertisement."

3 For example, Pogačnik and Črnič, "Ireligion."

4 Kenney, *Understanding Silicon Valley*.

5 Anderson, *The Movement and the Sixties*.

6 Brand, *Whole Earth Catalog* (1968), extended through 1972 and then updated infrequently as *The Last Whole Earth Catalog*, *The Whole Earth Epilog* (1974), *The Next Whole Earth Catalog* (1980), *The Essential Whole Earth Catalog* (1986), *The Whole Earth Ecolog* (1990), *The Millennium Whole Earth Catalog* (1994), and so on.

7 See, for example, an account by one member: Rheingold, *Virtual Community*.

8 Brand, *Media Lab*. On the role of engineers in shaping human futures, see the much earlier example by Hungarian-British physicist-engineer Dennis Gabor, *Inventing the Future*.

9 Brand, Whole Earth Catalog, 1; Turner, *From Counterculture to Cyberculture*.

10 Day, Logsdon, and Latell, *Eye in the Sky*; Taubman, *Secret Empire*; Lewis, *Spy Capitalism*; McDougall, *Heavens and the Earth*.

11 For example, Rong et al., "Smart City Architecture"; Bompard et al., "Congestion-Management Schemes."

12 Jordan, "Haussmann and Haussmannisation"; Winner, "Do Artifacts Have Politics?"; Taylor, *Berlin Wall*.

13 Bradley, "Unbelievable Reality of the Impossible Hyperloop"; Strauss, "Elon Musk."

14 United Nations General Assembly, "Treaty on Principles."

15 Wells, *Men Like Gods*.

16 Leach, *Runaway World?*, 1, 16.

17 Brand, *Whole Earth Catalog*, 1.

18 Ibid., *Whole Earth Discipline*, 1, 21. For a more critical stance, see Preston, *Synthetic Age*.

19 Brand, *Whole Earth Discipline*, 208.

20 Ibid., 13, 21. For an authoritative history of anthropogenic climate change, see Weart, *Discovery of Global Warming*. See also Moriarty and Honnery, "Nuclear Energy."

21 Keith, "Geoengineering the Climate."

22 Schiermeier, "Iron Seeding Creates Fleeting Carbon Sink."

23 Carbon Capture and Storage Association, http://www.ccsassociation.org/.

24 Royal Society, "Geoengineering the Climate."

25 Wolpert, "No Quick, Easy Technological Fix for Climate Change."

26 National Institutes of Health, "Insulin and Human Growth Hormone"; Tomiuk, Wohrmann, and Sentker, *Transgenic Organisms*.

27 Redenbaugh et al., Safety Assessment of Genetically Engineered Fruits and Vegetables; Bruening and Lyons, "Case of the Flavr Savr Tomato"; Tutelyan, *Genetically Modified Food Sources*.

28 Nicolia et al., "Overview of the Last 10 Years"; Committee on Genetically Engineered Crops, "Genetically Engineered Crops."

29 Brand, *Whole Earth Discipline*, 154–5; Potrykus, "Golden Rice and Beyond"; Mayer, "Golden Rice Controversy"; Dubock, "Politics of Golden Rice."

30 The growing literature on genetic engineering – like that on other forms of engineering – ranges from the narrowly technical to the more broadly questioning and interdisciplinary. See, for example, Setlow, *Genetic Engineering*; and Russo and Cove, *Genetic Engineering*.

31 Jordan and O'Riordan, "Precautionary Principle." On the problems with conventional twentieth-century technological systems, see Perrow, *Normal Accidents*.

32 Brand, *Whole Earth Discipline*, 217.

33 Ibid., 217.

34 Huxley, "Transhumanism," 13.

35 Tirosh-Samuelson, "Technologizing Transcendence."

36 Fuller, *Humanity 2.0*.

37 For example, Dvorsky, "Better Living through Transhumanism"; Verdoux, "Transhumanism, Progress and the Future."

38 Spilhaus, "Our New Age," 26 December 1965. 39 Belasco, "Synthetic Arcadias."

40 Vinge, "Coming Technological Singularity"; Eden and Moor, *Singularity Hypotheses*.

41 Moore, "Cramming More Components onto Integrated Circuits"; Byrne, Oliner, and Sichel, "Is the Information Technology Revolution Over?"

42 Toffler, *Future Shock*; *The Third Wave*; Toffler and Toffler, *Creating a New Civilization*. See also Halley and Vatter, "Technology and the Future as History"; and De Miranda, "Technological Determinism and Ideology."

43 Berube, *Nano-Hype*.

44 Berger, *Nano-Society*.

45 Drexler, *Engines of Creation*; Smalley, "Of Chemistry, Love and Nanobots."

46 "Nanotechnology and the Environment"; Health and Environment Alliance, "Nanotechnology and Health Risks."

47 *Star Trek: The Next Generation* (1987–94) explores the moral worth of synthetic humans via the android character Data but rejects the transhumanist Borg as re-engineered but dehumanized beings.

48 Stern, *Eugenic Nation*.

49 Dikötter, "Race Culture"; Bashford and Levine, *Oxford Handbook of the History of Eugenics*.

50 Huxley, *Brave New World*.

51 Teles, "Kludgeocracy in America."

52 This section extends my discussion in Franks, Hanscomb, and Johnston, *Environmental Ethics and Behavioural Change*, chap. 4.

53 Steffen, *Worldchanging*.

54 "Shallow" and "deep" ecology can be distinguished at a philosophical level, with the first focusing on utilitarian ethics and the second founded on virtue ethics.

55 Schumacher, *Small Is Beautiful*, 128. 56 Kirk, "Machines of Loving Grace"; "Appropriating Technology."

57 https://books.google.com/ngrams.

58 Directorate-General for Research and Innovation, "Options for Strengthening Responsible Research and Innovation," 3; Owen, Macnaghten, and Stilgoe, "Responsible Research and Innovation".

59 Directorate-General for Research and Innovation, "Options for Strengthening Responsible Research and Innovation," 35 (emphases added).

60 The term "wicked problem" was first defined as a class of planning problems in "open societal systems" that had inadequate theory for forecasting and a "plurality of objectives … and politics." See Rittel and Webber, "Dilemmas in a General Theory of Planning," 160. Rittel was a founder of the Design Methods Group (DMG) at University of California, Berkeley, during the 1960s, which advocated a rational and scientific approach to urban design. Its emphases were complementary to the work of Richard L. Meier, who joined Berkeley in 1967 and contributed to the *DMG Newsletter*.

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