II.E TECHNOLOGICAL CHANGE

Summary

Scenario 3 depends on continued technological innovation to ensure continued economic growth. We need to ask if there are features of such ongoing technological change which might be objectionable or which might even erode the conditions necessary for the achievement of Scenario 3.

Section II.E.1.a reviews forecasts of technological change for the period 1966-2000. These forecasts were wrong in many details but accurately predicted broad trajectories. Section II.E.1.b reviews forecasts for 2000-2025. We conclude that these forecasts are reasonable ones. Section II.E.1.c reviews projections of technologies beyond 2025. These are necessarily more speculative but are consistent with past and current trends and appear reasonable in broad outline.

The technologies forecast in the studies reviewed promise to increase the ability of humankind to manipulate the natural world by many orders of magnitude. Their widespread application has the potential to profoundly change the nature of life on earth, including human life. Importantly, these technologies are celebrated by a great many of their developers as driven by imperatives resistant to social control. Techno-global neoliberalism fosters the development of these technologies in ways that reinforce its present commanding position. If Scenario 3 is to be seen as a credible alternative, its supporters will need to understand the profound implications of the current technological trajectory, and establish the popular support and the institutions necessary to allow effective social oversight and regulation.

II.E.2 reviews the powerful new human genetic and reproductive technologies. These technologies have the potential to be uniquely destabilizing. If the goals of Scenario 3 and social democratic internationalism are to be realized many of the new human genetic technologies will need to be constrained and some will need to be proscribed.

Section II.E.2.b documents the vision of the genetically-enhanced human future that has, with little public attention, become almost a consensus view among prominent scientists in genetics, biotechnology and related fields.

Section II.2.c surveys policies that have been proposed and enacted to bring the new human genetic technologies under responsible societal control. We see that the needed policies have in fact already been enacted, piecemeal, in one country or another. The challenge before us now is to have these policies adopted in full and universally.

Section II.E.3 assesses the state of pubic opinion concerning biotechnology issues in general and human genetic technologies in particular. We see that opinion on these topics is at the moment still unformed, and survey responses vary widely depending on the wording of the questions asked. However, careful comparison of survey questions suggests that large numbers of people are able to make thoughtful distinctions between those technologies they would like to see allowed and those they would like to see proscribed.

Section II.E.4 concludes by assessing the implications of our review of the challenges of technological change for the credibility of Scenario 3.

II.E. TECHNOLOGICAL CHANGE

Scenario 3 depends upon ongoing technological innovation to ensure continued and ecologically benign economic growth. However, we need to ask if there are features of such ongoing technological change that might be objectionable, or that perhaps might even erode the conditions necessary for the achievement of Scenario 3. If so, we need to ask how we might constrain or forego these technologies, and at what cost. If the means by which these technologies are to be constrained are themselves objectionable or costly, then Scenario 3 might not be desirable, credible and compelling after all, and other scenarios would need to be reconsidered.

In this section we review and evaluate past and current projections of technological change. Then we assess the bearing that currently projected technological changes may have on the prospects for our quantitative and narrative scenarios of global development and for Scenario 3 in particular.

II.E.1. REVIEW OF PROJECTED TECHNOLOGICAL TRAJECTORIES

We begin by reviewing Kahn and Wiener's 1965 forecast of technological innovations likely to be realized by 2000. This allows a first, very rough assessment of the utility of such projections. Then we review the 1997 forecasts made by Coates et al. of technologies likely to be realized by 2025. Finally we review forecasts offered by a variety of authors of the nature of technologies that might be realized later in this century and beyond.

II.E.1.a. The Year 2000: Herman Kahn and Anthony Wiener (1967)

Kahn and Wiener assumed that human civilization would develop along a set of trends that they suggested had been underway in the West for at least the last two centuries, and which, they believed, were about to spread to the rest of the world. These trends are shown in **IIE-1**.

BOX IIE-1. Kahn and Wiener's List of Long-Term Trends
[Kahn and Wiener (1967)]

1. increasingly empirical, this-worldly, secular, humanistic, pragmatic, utilitarian, contractual, epicurean or hedonistic cultures
2 bourgeois, bureaucratic, meritocratic, democratic (and nationalist?) elites
3. accumulation of scientific and technological knowledge
4. institutionalization of research, development, innovation and diffusion
5 worldwide industrialization and modernization
6. increasing affluence and (recently) leisure
7. population growth
8. urbanization and (soon) the growth of megalopolises
9. decreasing importance of primary and (recently) secondary occupations
10. increased literacy and education
11. increasing capacity for mass destruction
12. increasing tempo of change
13. increasing universality of these trends

The growth of technological knowledge is identified explicitly as one of these trends. Nearly half of the trends shown in IIE-1 are bound up in one way or another with the development and spread of technology. Kahn and Wiener recognized the critical importance of technology and devoted a full chapter of their book to a review of technological innovations we could expect by 2000. Their forecast is shown in **IIE-2.**

An assessment of this forecast is shown in **IIE-3**. Perhaps 40-50% of the items listed might be considered to have come to pass. This figure rises to 50-60% if we include those items that are today technologically feasible but which have not been developed largely because the need or desire for them has not been strong. If we include the close calls--those innovations that we might reasonably expect will be realized within the next 10 to 15 years --the percentage rises to 60-70%.

The items on Kahn and Wieners' list can be classified according to more general purposes, functions or applications. One classification is shown in **IIE-4**.

II.E.1.b. 2025: Scenarios of US and Global Society Reshaped by Technology: Joseph Coates, John Mahaffie and Andy Hines (1997)

Coates et al. present a carefully considered forecast of technological innovations that they expect should be realized during the first quarter of the 21st century. Some of the major innovations they forecast are shown in **IIE-5.**

Coates et al. assume a "no surprises" scenario of social, political and economic development that provides the context and motivation for the scientific and technological developments analyzed and forecast. For the most part these projections represent a continuation through 2025 of the civilizational trends identified by Kahn and Wiener in 1965.

Four "enabling technologies" are identified as "primary drivers of change" over the coming quarter century: information technologies, materials technologies, genetic/biological technologies, and energy technologies. At a finer scale of resolution the items in the Coates et al. list fall pretty neatly into the categories derived from Kahn and Wiener's list shown in IIE-4

BOX IIE-2. Kahn and Weiner's List of Likely Technological Innovations by 2000

In their book, *The Year 2000: A Framework for Speculation on the Next Thirty-Three Years*, Kahn and Weiner presented this list of "One Hundred Technological Innovations Very Likely in the Last Third of the Twentieth Century."

1. Multiple applications of lasers and masers for sensing, measuring, communication, cutting, heating, welding, power transmission, illumination, destructive (defensive), and other purposes
2. Extreme high-strength and/or high-temperature structural materials.
3. New or improved superperformance fabrics (papers, fibers, and plastics).
4. New or improved materials for equipment and appliances (plastics, glasses, alloys, ceramics… , and cements).
5. new airborne vehicles (ground-effect machines, VTOL/STOL, super-helicopters, giant and/or supersonic jets.
6. Extensive commercial application of shaped-charge explosives.
7. More reliable and longer-range weather forecasting.
8. Intensive and/or extensive expansion of tropical agriculture and forestry.
9. New sources of power for fixed installations (e.g., magnetohydrodynamic, thermionic…, and radioactivity).
10. new sources for power for ground transportation (storage battery fuel cell, propulsion [or support] by electro-magnetic fields, jet engine, turbine, and the like).
11. Extensive and intensive worldwide use of high altitude cameras for mapping prospecting, census, land use, etc.
12. New methods of water transportation (such as large submarines, flexible and special purpose "container ships")
13. Major reduction in hereditary and congenital defects
14. Extensive use of cyborg techniques (mechanical aids/ substitutes for human organs, senses, limbs, etc.)
15. new techniques for preserving or improving the environment
16. Relatively effective appetite and weight control
17. New techniques and institutions for adult education
18. New and useful plant and animal species
19. Human "hibernation" for short periods (hours or days) for medical purposes.
20. Inexpensive design and procurement of unique items through computerized analysis & automated production
21. Controlled and/or supereffective relaxation and sleep
22. More sophisticated architectural engineering (e.g. geodesic domes, "fancy" stressed shells, pressurized skins,)
23. New or improved uses of the oceans (mining, extraction of minerals, controlled "farming" source of energy)
24. Three-dimensional photography, illustrations, movies, and television
25. Automated or more mechanized housekeeping and home maintenance
26. Widespread use of nuclear reactors for power
27. use of nuclear explosives for excavation and mining, generation of power, creation of high temperature-high-pressure environments, and/or as a source of neutrons or other radiation
28. General use of automation and cybernation in management and production
29. Extensive and intensive centralization (or automatic interconnection) of current and past personal and business information in high-speed data processors
30. Other new techniques for surveillance, monitoring, and control of individuals and organizations
31. Some control of weather and/or climate.
32. Other experiments with the overall environment (e.g., permanent increase in C-14 and temporary creation of other radioactivity by nuclear explosions, and the deliberate increasing generation of CO_2 in the atmosphere.)
33. New and more reliable "education" & propaganda techniques for affecting public and private human behavior.
34. Practical use of direct electronic communication with and stimulation of the brain
35. Human hibernation for relatively extensive periods (months to years)
36. Cheap and widely available central war weapons and weapon systems
37. New and relatively effective counterinsurgency techniques (and perhaps also insurgency techniques)
38. New techniques for very cheap, convenient, and reliable birth control
39. New, more varied and more reliable drugs for control of fatigue, relaxation, alertness, mood, personality, etc.
40. Capability to choose the sex of unborn children.
41. Improved capability to "change" sex of children or adults
42. Other genetic control and/or influence over the "basic constitution" of an individual.
43. New techniques and institutions for education of children
44. General and substantial increase in life expectancy, postponement of aging, and limited rejuvenation
45. Generally acceptable and competitive synthetic foods and beverages (e.g., carbohydrates, fats, proteins, enzymes, vitamins, coffee, tea, cocoa, and alcoholic liquor)
46. "High quality" medical care for undeveloped areas (medical aides, referral hospitals, artificial blood plasma)
47. Design and extensive use of responsive and supercontrolled environments for private and public use

(more…)

BOX IIE-2. (cont'd)

48. Physically nonharmful methods of overindulging
49. Simple techniques for extensive and "permanent" cosmetological changes (perhaps complexion and skin color)
50. More extensive use of transplantation of human organs
51. Permanent manned satellite and lunar installations-interplanetary travel
52. Application of space life systems or similar techniques to terrestrial installations
53. Permanent inhabited undersea installations and perhaps even colonies
54. Automated grocery and department stores
55. Extensive use of robots and machines "slaved" to humans
56. New uses of underground "tunnels" for private and public transportation and other purposes
57. Automated universal (real time) credit, audit and banking systems
58. Chemical methods for improving memory and learning
59. Greater use of underground buildings
60. New and improved materials and equipment for buildings and interiors (e.g., variable transmission glass, heating and cooling by thermoelectric effect, and electroluminescent and phosphorescent lighting).
61. Widespread use of cryogenics
62. Improved chemical control of some mental illnesses and some aspects of senility.
63. Mechanical and chemical methods for improving human analytical ability more or less directly
64. Inexpensive and rapid techniques for making tunnels and underground cavities in earth or/or rock
65. Major improvements in earth moving and construction equipment generally
66. New techniques for keeping physically fit and/or acquiring physical skills
67. Commercial extraction of oil form shale
68. Recoverable boosters for economic space launching
69. individual flying platforms
70. Simple inexpensive home video recording and playing
71. Inexpensive high-capacity, worldwide, regional and local communication (perhaps using satellites & lasers)
72. Practical home and business use of "wired" video communication for both libraries or other sources) and rapid transmission and reception of facsimiles (possibly including news, library materials, commercial announcements, instantaneous mail delivery, other printouts, and so on)
73. Practical large-scale desalination
74. Pervasive business use of computers for the storage, processing and retrieval of information
75. Shared time (public and interconnected?) computers generally available to home & business on a metered basis.
76. Other widespread use of computers for intellectual and professional assistance (translation, teaching, literature search, medial diagnosis, traffic control, crime detection, computation, design, analysis, etc.
77. General availability of inexpensive transuranic and other esoteric elements
78. Space defense systems
79. Inexpensive and reasonably effective ground-based BMD
80. Very low-cost buildings for home and business use
81. Personal "pagers" (perhaps even two-way pocket phones) and other personal electronic equipment, for communication, computing and data processing program
82. Direct broadcasts from satellites to home receivers
83. Inexpensive (less than $20), long lasting, very small battery operated TV receivers
84. Home computers to "run" household and communicate with outside world
85. Maintenance-free, long life electronic and other equipment
86. Home education via video and computerized and programmed learning
87. Stimulated and planned and perhaps programmed dreams
88. Inexpensive (less than one cent a page),rapid high-quality black and white reproduction; followed by color and high-detailed photography reproduction-perhaps for home as well as office use
89. Widespread use of improved fluid amplifiers
90. Conference TV (both closed circuit and public communication system)
91. Flexible penology without necessarily using prisons (by use of modern surveillance, monitoring, and control)
92. Common use of (long lived?) individual power source for lights, appliances, and machines
93. Inexpensive worldwide transportation of humans and cargo
94. Inexpensive road-free (and facility-free) transportation
95. New methods for rapid language teaching
96. Extensive genetic control for plants and animals
97. New biological/chemical methods to identify, trace, incapacitate, or annoy people for police and military uses
98. New and possibly very simple methods for lethal biological and chemical warfare
99. Artificial moons and other methods for lighting large areas at night
100. Extensive use of "biological processes" in the extraction and processing of minerals

BOX IIE-3. Assessment of Kahn and Wiener's 1967 Forecasts

I assessed each of the100 items shown in Box IIE-2 according to how closely they fit the descriptions listed below. "Sympathetic" assessments resolved ambiguities in ways that gave a higher percentage of good predictions. "Unsympathetic" assessments gave a lower percentage of good predictions.

description	sympathetic assessment	unsympathetic assessment
The innovation has occurred, precisely as or very nearly as he described it	41	26
The innovation has occurred, at least roughly or in the spirit of his description	10	15
The innovation has not occurred but is clearly feasible and is reasonably likely over the next 10-20 years	10	10
The innovation is clearly feasible, but the need or desire for it has not developed	13	9
The feasibility of the innovation is still uncertain; at best its realization is many decades away	13	23
The innovation is very likely infeasible, and the authors should have known better than to include it in this list	4	9
The authors' description is too general or ambiguous to allow an assessment to be made	9	8

BOX IIE-4. A Classification of Kahn and Weiner's 100 Technological Innovations

Kahn and Wiener's predictions shown in Box IIE-2 can for the most part be assigned to one or another of these general categories of purpose, function or application:

*Manufacture and build things to higher performance standards, faster and cheaper.
*Transport matter, energy and information, in more flexible forms, faster and cheaper.
*Manipulate the biogeophysical processes of the earth.
*Manipulate the bodies and behaviors of plants and animals.
*Enhance the physical and mental condition and abilities of children and adults.
*Expand options concerning health and reproduction.
*Extend human lifetimes
*Reduce the time and effort spent on household and personal maintenance activities.
*Extend human activities to the rest of the solar system and beyond.

BOX IIE-5. TECHNOLOGIES OF 2025 [Coates et al, 1997]

The items listed below were selected and summarized from different sections of Coates et al.'s book.

Theme: Advances in science and technology are extending humanity's ability to take an active role in "influencing, guiding, supervising and governing the natural and built environments of our planet."

1. The genetic components of 4,400 human diseases and disorders are identified and major progress has been made towards therapies. 2000 single gene disorders, such as Huntington's Cholera, polycystic fibrosis and kidney disease, have been eliminated. Physical and mental abilities are being enhanced through genetic technologies.

2. *In utero* alteration of traits is practiced with respect to such conditions as schizophrenia, diabetes, sexual predisposition, simple brain capabilities, and baldness.

3. Cloned human organs are allowed to be used as replacements for diseased organs. Cloning techniques also allow growth of organoids to produce needed hormones, enzymes and other substances that a person may be lacking.

4. Synthetic body parts are common, aided by targeted drug treatments. Persons who are blind, deaf or otherwise impaired have their abilities extended via advanced bio, neuro-bio, and information technologies.

5. Substantial progress has been made in mapping the cognitive modules of the brain.

6. Progress has been made towards brain-mind manipulation, largely via pharmaceuticals, to influence emotions, learning, sensory acuity, memory and other psychological states.

7. Foolproof DNA identification of individuals for forensic and legal purposes has been developed.

8. Geneticists administer gene therapies prenatally and in young children to manage the genes that promote and inhibit the aging process. Life expectancy of a person born in 2025 is 85. High levels of functioning throughout old age are normal.

9. The genome of prototypical plants, animals, and micro-organisms is fully understood, leading to more refined management, control and manipulation of their health, propagation or elimination. Up to 60% of crop losses in the US due to pests have been eliminated, along with Lyme disease and elephantiasis.

10. Food is synthetically and genetically manipulated to suit an individual's taste, nutritional needs and medical status. High-protein vegetables have been engineered to support vegetarian practices.

11. A new Green Revolution involves genetic engineering for greater photosynthetic efficiency, salt and drought tolerance, pest-resistance and self-propagation, along with extensive farmer management training and hi-tech irrigation systems.

12. Half-size genetically engineered diary cattle produce high volumes of milk but consume only 2/5 the forage of full size cattle. Dairy milk has been fine-tuned to human needs, with variations for children, adults, and those intolerant of milk components. Farm animal diseases have been largely eliminated by cloning.

13. Closed-loop materials use, product lifetimes 5 times longer than in 1995, and extensive use of the 3R's (recycling, reclamation, remanufacturing) are standard.

14. Mining, logging and drilling are targeted, minimalist, and clean. Trees used for paper pulp are genetically engineered to allow nonchemical pulping.

15. Animals are used as bioreactor "gene-pharms" to produce pharmaceuticals, enzymes, hormones and other products.

16. Water and power is supplied to the US, Mexico and Canada through an integrated continental grid. The Great Lakes and James Bay in Canada, serve as major water storage and distribution reservoirs. Losses due to drought have been reduced by 75%. Bio-membrane technologies make large-scale water salinization practical.

17. There is a worldwide, broadband, fiber optic network of networks giving universal "fiber to the home". Face-to-face, voice-to-voice, person-to-data and data to data communications is available to and from any place and at any time. Terminals and displays are ubiquitous. Three dimensional, very high definition, full VR interface is standard. Computers are 5,000 to 10,000 times faster than in 1990.

18. Language translation is effective in printed telecommunications for restricted but practically significant vocabularies.

[more…]

Box IIE-5 Technologies of 2025 (cont.)

19. Micro-machines, smart surfaces and dynamic structures are ubiquitous and unobtrusive. Infrastructure is self-monitoring and to a limited degree self-repairing.

20. Manipulation at molecular or atomic levels allow manufacturers to customize materials for highly specific functions.

21. Standardization, modular design, passive safety systems, automation and computer monitoring have increased the safety and efficiency of light water reactors. Radioactive wastes are being stored using glass ceramics and subduction zone injections.

22. Most cars are gasoline hybrids: gasoline-electric, ethanol methanol-electric, reformulated gasoline-electic, compressed natural gas-gasoline, hydrogen-gasoline, and hydrogen-electric.

23. Advances in information, materials and bio technologies have contributed to significant energy efficiencies and have reduced the rate of growth of energy use dramatically.

24. “Smart homes” and commercial facilities with computer controlled EMS’s (energy management systems) are standard.

25. Materials and manufacturing processes mimic biological ones: honey combs and cellular structures, wood-plastic forms using ligino-cellulose as a feedstock, and bio-compatible polymers, ceramics and glasses.

26. Construction costs have been dramatically reduced and made more sensitive to environmental constraints through virtual reality modeling and design, automatic component production, modular units, and automatic site preparation.

27. “Restyling” is common: outer features of cars, furniture, houses, etc. are easily and cheaply replaced and modified, while inner structural features are built for very long life.

28. “Taggants” allow rapid, automated identification of the chemical and compositional structure of materials, thus facilitating recycling, reproducing and remanufacturing.

29. Combinatorics, genetic algorithms, and evolutionary approaches are applied to chemical engineering, pharmaceuticals, product design and other technologies, and to problem-solving in general.

30. 40,000 types of plastics are in use in 2025, up from 15,000 in 1990, used mostly in small-volume, special applications. By contrast high-volume plastics, metals and glasses for containers, food wrappers and packaging are limited to a very few species to make recycling economical.

31. Macroengineering projects to tap resources, reverse environmental degradation, provide living space, and construct intercontinental and global scale transportation and information linkages are underway.

32. Higher volumes of travel are supported through a fully integrated system of intelligent vehicle highway systems, (IVHS), mag-lev and other fast-rail systems, fixed and rotary winged aircraft, hovercraft, ships, personal rapid transit, subways and more. Information technology coordinates and monitors transit of people and goods; collects fees, tolls, fares and tariffs; enforces regulations; governs autopilot systems and automatic cargo handling; and weights trucks. The costs of sea cargo transport are markedly reduced by the use of factory ships, magnetohydrodynamic drives, and biotech tools for cleaning barnacles off keels.

33. Info-tech allows 40% of the workforce to work in distributed networks. Workers increasingly use high-tech mobile offices to spend more time at customer and vendor sites, while keeping in easy touch with the home offices via voice, video and print.

34. Family cars are commonly small vans fully equipped as mobile video/info centers.

35. Robots have solved the “bin-picking problem” and do multiple tasks by voice command without reprogramming. “Dark factories” are in increasing use.

36. Extensive global sensing networks of satellites, remote observation devices, and ground-based sensors help monitor pollution, allow pricing approaches to global environmental regulation, and assure compliance with global environmental treaties.

37. Vigorous commercial exploitation of space focuses on satellite communications, earth observation, launch and transport services, space robotics, materials processing, and the processing, interpreting and selling of space data.

38. The International Space Station was fully operational by 2015. Human landing on Mars is set for 2030. Preparations are underway for human exploration of the outer solar system.

The Coates et al. study differs notably from Kahn and Wiener's in its reduced concern with military technologies and its heightened concern with technologies that address environmental problems. These differences reflect two of the few ways in which the world of 1997 is truly different from the world of 1965: the end of the Cold War and the rise of the environmental movement. Coates singles out "environmentalism" as a fifth "primary driver of change" over the coming decades.

If we straightforwardly adopt the results of our assessment of Kahn and Wiener's 1967 forecast as a guide, we might expect that upwards of 50% of the innovations listed in IIE-5 should come to pass by 2025.

However, this is may be a conservative estimate. Kahn and Wiener's list contains a number of idiosyncratic items (e.g., human "hibernation"), and the Coates et al. list might be overly cautious. Many of Coates' forecasts represent the diffusion and conventional modification-through-use of technologies that are already at or very near operational and commercial status. It might not be unreasonable to expect that 60-70% of the innovations forecast by Coates are likely to be realized.

Is a world that is sustained and shaped by the technologies described in IIE-5 a desirable world? Persons and societies that hold different values would answer this question in different ways. However, a close inspection of the items on the Coates et al. list suggests that most, although not all, appear to have to larger constituencies that would be inclined to support them, than they do constituencies that would be inclined to oppose them, giving current social, economic and political values.

Two technologies included in the Coates et al. list might not command general support. Although current opinion surveys suggest acceptance of the application of genetic technologies to plants and animals, and to humans for the prevention and treatment of disease and disability, they show more ambivalence about proposals to genetically enhance human traits such as life span, physical appearance and mental abilities.[1] Also, very large-scale macroengineering projects often have sufficiently negative impacts on enough constituencies to motivate a successful opposition. However, even if these two red-flag items were prevented from becoming important features of our technological environment, the development of the remainder of the items on Coates' list would ensure that the overall content, look and feel of Coates' vision would largely still be realized.

Of course, even if each item on Coates' list, considered separately, was felt by most people to confer a net benefit, the complete package, taken as a whole, might not be. And even if the complete package was felt to be desirable on its own terms, it might still be challenged if people felt that its realization would commit us to a trajectory of technological development whose consequences at a later date would be undesirable.

This second possibility is particularly relevant to our concern with global development over long periods of time. In the next section we review several studies that speculate on the nature of technological innovation over the full course of the 21st century, and beyond.

II.E.1.c. Beyond 2025: Long-Range Visions of Technological Change

Noted authors and texts that consider long-range technological prospects are listed in **IIE-6**. Topics that appear often in these texts are shown in **IIE-7**. Longer-range projections developed by Michio Kaku are shown in **IIE-8**.

These authors claim that science and technology have brought humankind to the verge of a profound transformation. They believe that over the coming century we will develop unprecedented powers to manipulate all aspects of the natural world, including our own bodies and minds. The first applications of these new powers will in turn give rise to even greater transformative possibilities, the likes of which are quite literally beyond our imagination today.

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[1] See the full discussion of public opinion about technology and genetic engineering in Section II.E.3 below.

BOX IIE-6. Texts that Speculate on the Long-Range Technological Future

Eric Drexler, *Engines of Creation.* (1986)
Eric Drexler, *Nanosystems: Molecular Machinery, Manufacturing and Computing* (1992)
Freeman Dyson, *Infinite in All Directions* (1988)
Freeman Dyson, *Imagined Worlds* (1997)
Robert Ettinger, *The Prospect of Immortality* (1964)
Richard Feynman, "Plenty of Room at the Bottom" in:*Engineering and Science* 23 (Feb 1960)
Ben Finney and Eric Jones, *Interstellar Migration and the Human Experience* (1985)
Neil Gershenfeld, *When Things Start to Think* (1999)
Michio Kaku, Visions: *How Science will Revolutionize the 21st Century* (1997)
Kevin Kelly, *Out of Control. The Rise of Neo-Biological Civilization* (1994)
Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (1999)
Steven Levy, *Artificial Life: The Quest for A New Creation.* (1992)
Ralph Merkle, "Molecular Repair of the Brain" in: *Cryonics* 10 (Oct. 1989)
Marvin Minsky, *The Society of Mind* (1986)
Hans Moravec, *Mind Children: The Future of Robot and Human Intelligence* (1988).
Hans Moravec, "Pigs in Cyberspace" in: *Extropy* (Winter 1993)
William O'Neill, *The High Frontier: Human Colonies in Space* (1977)
Heinz Pagels, *The Dreams of Reason* (1988)
Gregory Paul and Earl Cox, *Beyond Humanity: Cyberevolution and Future Minds* (1996)
Lee Silver, *Remaking Eden: How Cloning and Beyond Will Change the Human Family* (1998)
Gregory Stock, *Metaman: The Merging of Humans and Machines into a Global Superorganism* (1993)
Frank Tipler, *The Physics of Immortality* (1994)

Numerous articles on aspects of the Extraordinary Future have been published in journals such as *Whole Earth Review*, *WIRED*, and *EXTROPY: the Journal of Transhumanist Thought.* Many Web sites are devoted to these topics as well.

BOX IIE-7. Topics Common to Discussions of the Long-Range Technological Future

This is a list of topics that appear repeatedly in works concerning the development of technology over the next century. These topics include foundational technologies, applications, scientific and technological disciplines and theories, and topics of general interest.

* nanotechnology, picotechnology and femtotechnology
* robots, androids, and cyborgs
* cellular automata, artificial life, artificial consciousness and artificial intelligence
* virtual reality, genetic algorithms, fuzzy logic and neural networks
* expert programs, knowbots and distributed intelligence
* complexity theory, chaos theory, and theories of spontaneous order
* genetic engineering, germline manipulation, cloning and body/mind enhancement
* human evolutionary biology and evolutionary psychology
* new growth theory, biomics, agorics and facultative anagorobes
* cyberlife, cyberbeings, avatars, and cybersex
* life extension, cryonics and immortalism
* transhumanism and posthumanism
* morphological freedom, transbiomorphosis and ectogenesis
* smart drugs, smart machines, and smart surfaces
* grey goo, red goo, green goo, blue goo, khaki goo and ubergoo
* galactic & extra-galactic colonization, terraforming, star-lifting, stellar husbandry
* Dyson Spheres, O’Neill colonies, Kardaschev types, and Loftstrom loops
* the “Singularity:” its nature, developmental path, and expected date of arrival

BOX IIE-8. PROJECTIONS FOR 2020-2050 AND 2050-2100

In *Visions: How Science Will Revolutionize the 21st Century,* physicist Michio Kaku assesses the state and future of science and technology. He suggests developments that can be expected over three periods: 2000-2020, 2020-2050, and 2050-2100. His projections for 2000-2020 are similar to those of Coates et al. for 2000-2025. His projections for the later two periods include the items below. His projections are in general more conservative than those of most authors writing on this topic.

2020-2050

* By 2020 the limits of silicon chip technology will have been reached; further increases in computational power will require optical, DNA, quantum or other technologies.
* True robot automatons that have common sense, can understand human language, can recognize and manipulate objects in their environment, and can learn from their mistakes.
* Genuine artificial intelligence and effective expert systems permeates the Internet; the entire stock of human knowledge is available on the internet
* Genomes for all significant life forms mapped and sequenced. Major focus is functional analysis.
* Many complex polygenic traits will be fully understood, eg. arthritis, autoimmune diseases, schizophrenia, the aging process, facial features.
* Germline gene therapy, and human cloning, will be practical, if not banned.
* Growing and implanting new organs, including complex ones such as the heart and the hand, will be as common as kidney transplants today, especially as we extend the life span.
* Tissue engineering will have advanced.
* Mapping and understanding complex neural/brain behavior will have advanced.
* Deep bionics will have advanced, e.g., neural-chip connections for simple muscular functions.
* First commercial nuclear fusion plant will be operative.
* Room temperature superconductors w/ commercial applications spawn a 2nd industrial revolution.
* First practical nanotechnology applications will be realized.
* Solar electric-ionic rocket engines: solar cells ionize xenon gas and electric plates accelerate the ions to create low, continuous thrust; interplanetary travel inexpensive and commonplace.
* Long-haul interplanetary missions traverse deep space. We have a robot base on the moon, a manned Mars science colony, and manned probes of the asteroid belt and comets.

2050-2100

* Quantum computers will be operational.
* Manipulation of age genes, tissue engineering and other biotechnologies will extend the typical human lifetime to 150 years.
* Nuclear fusion will be globally widespread.
* All organs except the brain will be growable and replantable.
* Robots that are self-aware will serve as "secretaries butlers, assistants and aides."
* The "deep structure" of human genetic processes will be understood.
* Novel human organs will be engineered.
* New life forms will be constructed.
* Some forms of integrated human/computer functioning will be practicable.
* The neural processes of the brain will be completely mapped; behavior will be deeply understood.
* Research on rockets that can reach nearby stars, perhaps using interstellar hydrogen ramjet fusion engines, will be advanced. Unpiloted, decades-long flights will be planned. Plans will have begun for the first space colonies.

Over the past fifteen years this claim has acquired new momentum in the wake of real breakthroughs in information technology, genetic engineering and neurobiology, the spread of personal computers and the Internet, the pending completion of the Human Genome project, and other developments.

The vision of a human future radically transformed by deep technology gained coherence as a world view in the late 1980's with the publication of *Engines of Creation* by Eric Drexler. This book popularized *nanotechnology* as the foundational technology of the human future.

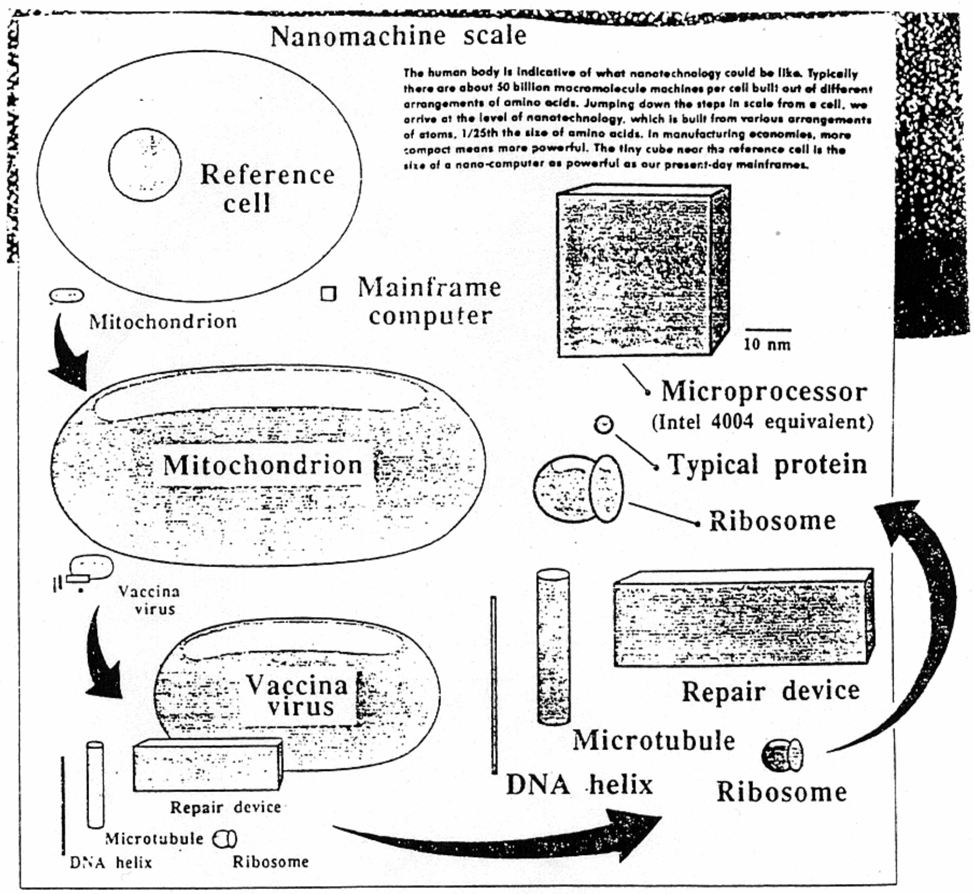
The term "nanotechnology" refers to the precise manipulation of matter and energy at the level of individual atoms and molecules. Drexler suggested that it should be possible to build a computer with the power of an IBM mainframe no bigger than a single-celled bacterium (see **IIE-9**). Components would be constructed of molecular-scale rods, gears, wheels, etc. Such a computer could guide equally small mechanical devices, called *assemblers,* that could manipulate atoms and molecules one at a time and thus construct literally anything, including reproductions of themselves. This prospect of nano-scale computers and assemblers gave new impetus to speculation on all sorts of technological capabilities that up until that point had seemed constrained by the limits of macro-scale engineering.

Kevin Kelly, editor of *WIRED* and former editor of the *Whole Earth Review,* draws on possibilities opened by nanotechnology in offering his vision of the coming "neo-biological civilization." He envisions

> "…mutating buildings, living silicon polymers, software programs evolving off-line, adaptable cars, rooms stuffed with coevolutionary furniture, gnatbots for cleaning, manufactured biological viruses that cure your illnesses, neural jacks, cyborgian body parts, designer food crops, simulated personalities, and a vast ecology of computing devices in constant flux." (1994 p 472)

Kelly's account is only slightly more dramatic than Coates', which itself draws heavily on the spirit of nanotechnology. The possibilities become more challenging when we look to the decades beyond the Coates et al. reference date of 2025.

BOX IIE-9 Nanotechnology
[Reprinted from Drexler (1987)]



Among the dominant themes in the literature that considers this period are those concerning the enhancement of cognitive abilities, whether human or mechanical. Hans Moravec, Director of the Mobile Robot Lab at Carnegie-Mellon University, has considered the possibility that human minds and consciousness could be transferred from brains to machines, as described in **IIE-10.**

A repeated theme in the literature of the Extraordinary Future [2] concerns the prospects for human endeavors beyond the earth, typically of gargantuan scale. An example is David Criswell's detailed scenario of space colonization described in **IIE-11** and **IIE-12.**

Many authors join notions of the machine embodiment of consciousness with the desire to expand consciousness beyond the confines of the earth. Moravec (1992) says,

> "There are about 10^56 atoms in the solar system. I estimate that a human brain-equivalent can be encoded in less than 10^15 bits. If a body and surrounding environment take a thousand times more storage in addition, a human with immediate environment might consume 10^18 bits. An equivalent Artificial Intelligence should probably get by with less, since it does without the body-simulation 'life support'… So a city of a million human-scale inhabitants might be efficiently stored in 10^24 bits. If the atoms of the solar system were cleverly rearranged so that every 100 could represent a bit, then a single solar system could hold 10^30 cities—except by the time intelligence has expanded that far, more efficient ways of using space-time would surely have been discovered, increasing the number much further." (p 5)

A particularly encompassing development of these themes is that of Tulane University astrophysicist Frank Tippler. He asks, "Can we imagine a way in which human society might live, and grow, forever?" His affirmative answer involves colonization of the galaxies by conscious machines and the manipulation of gravitational collapse, as described in **IIE-13**.

Speculation about the Extraordinary Future been influenced in recent years by the notion of the "Singularity," defined by Vernor Vinge (1981) as "the postulated point or short period in our future when our self-guided evolutionary development accelerates enormously (powered by nanotechnology, neuroscience, artificial intelligence or perhaps uploading) so that nothing

[2] I adopt here the term used by Paul and Cox (1997) to refer to a future profoundly transformed over the coming decades by technologies of the sort listed in Box IIE-7.

BOX IIE-10. UPLOADING MINDS
[from: Hans Moravec, *Mind Children* (1988)]

"You've just been wheeled into the operating room. A robot brain surgeon is in attendance...You are fully conscious. The robot surgeon opens your braincase and places a hand on the brain's surface. This unusual hand bristles with microscopic machinery, and a cable connects it to the mobile computer at your side. Instruments in the hand scan the first few millimeters of brain surface... These measurements allow the surgeon to write a program that models the behavior of the uppermost layer of the scanned brain tissue. This program is installed in a small portion of the waiting computer and activated... You are given a push-button that allows you to momentarily 'test drive' the simulation, to compare it with the functioning of the original tissue. When you press it, arrays of electrodes in the surgeon's hand are activated... They are programmed to inject the output of the simulation into those places where the simulated tissue signals other sites... You press the button, release it, and press it again. You should experience no difference. As soon as you are satisfied, the simulation connection is established permanently. The brain tissue is now impotent... Microscopic manipulators on the hand's surface excise the cells in this superfluous tissue and pass them to an aspirator, where they are drawn away.... The surgeon's hand sinks a fraction of a millimeter deeper into your brain....the process is repeated for the next layer, and soon a second simulation resides in the computer... Layer after layer of the brain is simulated, then excavated. Eventually your skull is empty, and the surgeon's hand rests deep in your brainstem. Though you have not lost consciousness, or even your train of thought, your mind has been removed from the brain and transferred to a machine. In a final, disorienting step the surgeon lifts out his hand. Your suddenly abandoned body goes into spasms and dies. For a moment you experience only quiet and dark. Then, once again, you can open your eyes. Your perspective has shifted. The computer simulation has been disconnected from the cable leading to the surgeon's hand and reconnected to a shiny new body of the style, color and material of your choice. Your metamorphosis is complete." (p 109)

Box IIE-11. INTERPLANETARY AND INTERSTELLER HABITATION
[source: David Criswell, *Solar System Industrialization: Implications for Interstellar Migrations* (1985)]

Criswell presents detailed proposals for the expansion of human habitation throughout the solar system and beyond, as illustrated in IIE-12. The expansion takes place in several stages:

I. Habitation of the Lagrange Wells (L4 and L5)

Criswell estimates that it would be more economical to build independent orbiting space habitats, called *space homes,* than it would be to colonize the moon or Mars. The space homes would be constructed in the gravitational wells L4 and L5 located in front of and behind the moon in its orbit around the Earth. Each space home would support 1 million people. Criswell projects that raw materials from the moon and available asteroids would allow construction of 240,000 space homes by 2200, allowing a total human population of 240 billion.

II. Planet Lifting

If we wanted to continue to expand beyond 2200 we could begin to disassemble the planet Jupiter and convert it into space homes. Jupiter could provide raw materials for about 400 years of continued growth.

III. Sun Lifting

If we wished to expand much further we would have to disassemble the sun. Interestingly, this action could *extend* the lifetime of the sun beyond its current estimated span of 5 billion years. "If Sol could be gently unwrapped of its outer layers and converted into white dwarf form, then the new dwarf could live 1,150 times the currently estimated age of the Universe (20 billion years)." Criswell details several approaches to sun-lifting. In one, a ring of very large solar-powered particle accelerators orbits the sun. Directed particle beams create a dynamic magnetic field close to the sun that propels matter from the solar atmosphere out through "holes" located over the north and south poles. As the matter cools complex elements are formed and are later mined. Sun-lifting would take about 300 million years. Over that time human civilization would have been able to grow to a population of 2x10^21, occupying 2x10^12 earth-equivalent space home habitats.

IV. Inter-Stellar Migration

Criswell suggests that the technology of stellar-lifting would allow us to forego concern over the presence or condition of planetary systems, which in any event represent minuscule resources, and simply colonize the galaxy star-by-star.

BOX IIE-12 Interplanetary and Interstellar Habitation (figures)
[Reprinted from Finney & Jones, 1985]

Figures 1 and 2 might be compared with the scenarios originally considered in Box IA-1.

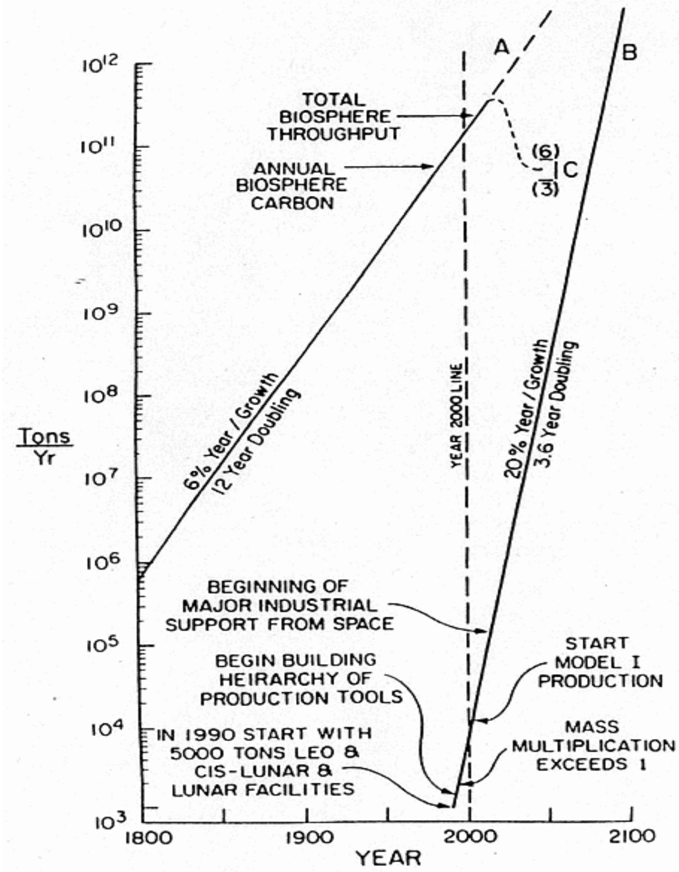


Figure 1. Annual Projected Production of "Demandite."

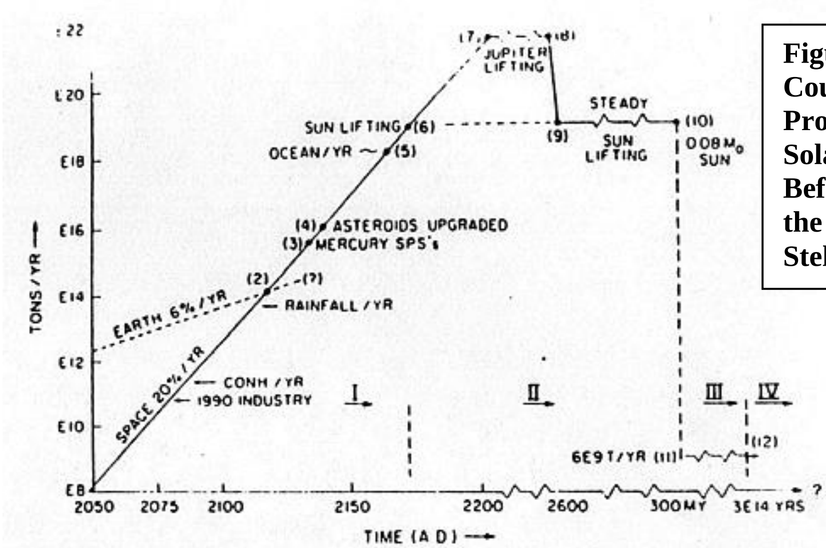


Figure 2. The Course of Mass Processing in the Solar System Before and After the Period of Stellar Husbandry.

BOX IIE-13. ETERNAL LIFE
[source: Frank Tipler, *The Physics of Immortality* (1994)]

Tipler argues that natural resource constraints and the eventual death of the sun require that "Life, if it is to continue, must leave the Earth and colonize space."

Colonization would employ self-reproducing universal constructors with human-level intelligence, each weighing no more than 100 grams. These would be accelerated to 90% of light speed and reach Proxima Centauri in 10 years. Colonies would require 100-300 years to grow from 100 grams to full civilization status, after which they would launch new constructors towards the next star.

At these rates this schedule is feasible:

colonization of the Milky Way galaxy	600,000 years
colonization of the Andromeda galaxy	3 million years
colonization of the Virgo Cluster	70 million years

After 10^18 years life will have engulfed the Universe. However, the energy to power this universal civilization undergoes continual entropic degradation and will eventually approach zero. Tipler asks if there is a way that this "heat death" might be avoided. He notes that by the time we engulf it the Universe is expected to have reached its maximum expansion and to have begun its collapse. He says that if our descendants act in concert "life in the far future can easily force the Universe to collapse very rapidly in two directions while remaining the same size in the third direction*…This means that the directions of contraction will be hot spots and the other direction will be a cold spot. This temperature difference will power life in the far future."

As the Universe continues to collapse it approaches its "Omega Point" of zero volume, infinite density and infinite temperature. What happens to life then? Tipler says that although the Universe "exists for only a finite proper time, it nevertheless could exist for an infinite subjective time." It can do this because the conditions of increasingly higher density and temperature can, if appropriately manipulated, provide an infinite supply of energy for an infinite amount of information processing between any given point in time and the final Omega Point. And life, according to Tipler, is "information processing subject to selection."

Tipler notes that "since a human being has about 110,000 active genes, the human genome can code about 10^10^6 possible genetically distinct humans. Furthermore, the human brain can store between 10^10 and 10^17 bits… which implies that there are between 2^10^10 and 2^10^17 possible human memories. On this basis there are (10^10^6)x(10^10^17), or about 10^10^17, possible human states." While this is a large number it is still finite. Tipler expects that as the Universe approaches the Omega Point of infinite information processing ability it will be able to "emulate" all persons who have ever lived, or might have lived, and that they will live and be aware for an indefinite period of subjective time.

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* The technical term is a "Taub Universe", after U.C. Berkeley mathematician Abraham Taub.

beyond that time can be reliably conceived" [3] Authors and researchers for whom the notion of a technological Singularity is credible allow themselves to speculate only on the topic of how the Singularity might most rapidly be realized (**IIE-14**) [4]

Many authors believe that life extension should be among the earliest achievements of the Extraordinary Future, and that immortality, either as biological or mechanical beings, should not be far behind. Several of these authors have made plans to have their bodies cryonically suspended if they die before technologies of immortality have been developed.

The Extraordinary Future represents a fairly straightforward extension of those technologies forecast by Coates et al. in 1997 for 2025 and by Kahn and Wiener in 1967 for 2000. This can be seen by comparing the technologies listed in Box IIE-7 with the categories derived from Kahn and Wiener's 1967 list shown in Box IIE-4.

Authors writing about the Extraordinary Future typically claim that it is inevitable (see **IIE-I5**).[5] They offer several arguments. The argument from evolutionary psychology is that human beings have dispositions to behave, and to get pleasure from behaving, in ways that increase our abilities to understand and control our environment, accumulate resources, protect ourselves from harm, and to both compete and cooperate in ways that enhance these ends. On this view the desire to develop and use technologies of the sort that will give us the Extraordinary Future is a natural expression of the same human nature that motivated the development and use of pottery, stone arrowheads, and the alphabet. If the Extraordinary Future is possible, it is inevitable, because we find it desirable.

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[3] Vinge is a mathematician at California State University at San Diego. In mathematics a singularity exists at the point where a function approaches infinity, as the function $y = 1/x$ does as x approaches zero.

[4] Many enthusiasts of the Extraordinary Future believe that the Singularity will occur within 20-30 years, if not sooner. Other authors caution that it may not arrive for as long as 50-60 years.

[5] Compare these statements of inevitability with those in Box IIC-4 concerning the inevitability of a steady-state economy. Compare them also with statements about the inevitability of human genetic manipulation in Section II.E.2.b.

BOX IIE-14. PATHS TO THE SINGULARITY

1. In a paper delivered at a NASA symposium Vinge (1993) saw four paths that could independently lead to the Singularity:
    1) powerful computers wake up
    2) large computer networks wake up
    3) computer/human interfaces become so intimate that users may reasonably be considered superhumanly intelligent
    4) Biological science may provide the means to improve native human intellect.

2. Yudkowsky (1996) believes "the Singularity will occur through enhanced humans, not necessarily through computer technology." His projected path is:
    1.0) first-stage enhanced humans
    1.5) improved human-computer interface
    2.0) nanotechnology
    3.0) high-speed neurons
    3.5) additional neurons
    4.0) computer-class "Powers"

3. Porter (1997) takes the opposite view and suggests that there will be "de-novo" human-equivalent computer minds before major human brain manipulation or uploading is practical. The stages are:
    1) wiring diagrams for human brain
    2) abundant parallel computation
    3) virtual worlds with thousands of organisms with neural architectures inspired by 1
    4) selection of promising organisms/societies/neural architectures/etc. (using genetic algorithms and other tools employing natural section principles)
    5) return to 3; repeat until Singularity.

William Calvin (1993) cautions that if the Singularity is to be achieved quickly, say within 30-50 years, we will face at least three important challenges:

1. Ecology: Calvin cites Aldo Leopold on the dangers of unanticipated consequences that often follow the introduction of new species, in this case superhumans, into an ecosystem.
2. Values: Calvin says that "agreeing on values and implementing them *in silico*" is a bargaining process between humans and the superhumans, and that we might prefer to wait as much as several decades before allowing them to go free.
3. Reaction: "Human reactions to silicon superhumans could create enormous strains in our present civilization."

However, Calvin concludes that "I don't see realistic ways of 'buying time' to make this superhuman transition at a more deliberate pace. And so the problems of superintelligent machines will simply need to be faced head-on in the next several decades, not somehow postponed by slowing technological progress itself."

BOX IIE-15. THE INEVITABILITY OF THE EXTRAORDINARY FUTURE

Vernor Vigne (1993): "I have argued that we cannot prevent the Singularity, that its coming is an inevitable consequence of the humans' natural competitiveness and the possibilities inherent in technology…Even if all the governments of the world were to understand the 'threat' and be in deadly fear of it, progress toward the goal would continue… The competitive advantage—economic, military, even artistic—of every advance in automation is so compelling that passing laws, or having customs, that forbid such things merely assure that someone else will get them first." (p 4)

Gregory Paul and Earl Cox (1996): "In the end, it will not be possible to stop or dramatically slow down CyberEvolution at the local, state, province or national level. There will never be a consensus to stop CyberEvolution. Humans are inherently variable and divergent in their desires, and in a world of billions, there will always be great numbers who like and want what new technologies have to offer them. For the neo-Luddite movement to have any chance to succeed would require the imposition of a world government with extreme powers over all society, all industry, and all technology. It would have to be a global police state." (p 433)

San Francisco Examiner (2/27/95): "Technology leaders and government officials from the Group of Seven nations…gathered in Brussels…(to discuss) the broad implications of an economic and social restructuring born of the information revolution… (one) poised to bring about the most massive societal shifts worldwide since industrialization.". According to Martin Bangemann, vice president of the European Commission, "As I always tell people who have anxieties [about these massive shifts] you do not have a choice." (p A15)

A second argument acknowledges that many people may not in fact regard the Extraordinary Future as desirable, but goes on to say that so long as *some* people desire these technologies they will be realized. The reason is that people who possess these technologies will obtain abilities to prevail over those who do not, and thus over time the former will come to replace the later.

A third argument goes further and suggests that even if *nobody* regards the Extraordinary Future as desirable, it will *still* come to pass. Suppose everyone in the world vowed not to develop the technologies of the Extraordinary Future. Unfortunately, in a world of 6 billion people none of us can be sure than someone isn't lying, or deluding themselves about their own probable behavior. Because these technologies give their possessors great powers of life and death, none of us can afford to be at the mercy of those who might posses them. Thus, despite our preferences otherwise, we will all seek to develop the technologies of the Extraordinary Future.[6]

The Extraordinary Future envisions the end of human life as we know it. Princeton biologist Lee Silver anticipates that the spread of genetic engineering will lead to the eventual speciation of human beings.[7] Authors who believe that the uploading of human minds into machines is possible hold out the prospect of improved "post-biological" human lives. Others simply believe that artificial minds will be able to out-perform human minds, and that human beings will, either gracefully or otherwise, be replaced. Few authors find this undesirable; most celebrate it. Tipler says,

> "The death of *Homo sapiens* is an evil only for a racist value system. Our species is an intermediate step in the infinitely long temporal Chain of Being… It is a logically necessary consequence of eternal progress that our species become extinct!" (quoted in Regis, 1990 p.147).

[6] This argument has the structure of the game theoretic Prisoners' Dilemma.

[7] Section II.E.2 discusses human genetic and reproductive technologies in detail.

II.E.1.d. Evaluation and Discussion

The vision of the Extraordinary Future is indeed extraordinary. How might we evaluate it?

It is possible that the authors noted above don't really believe what they are saying, but this is not likely. Tipler tells of the time his young daughter asked him if she would, in fact, find eternal life as the Universe approached its Omega Point: "I realized I had to tell her what I really believed. I told her, 'yes'." [8]

It might be argued that the Extraordinary Future is the province of second-rate minds, and can be taken less seriously for that reason. This is not likely, either. While the topic has attracted its share of *poseurs,* its leading authors include some of the most respected scientists of our time. Here is noted neurophysiologist William Calvin (1993):

> "Even the first 'work-alike" computer will be recognizably 'conscious'…And I don't mean trivial aspects of consciousness such as aware, awake, sensitive, and arousable. It will likely include focusing attention, mental rehearsal, abstraction, imagery, subconscious processing, 'what-if' planning, decision-making, and the narratives we humans tell ourselves when awake or dreaming. To the extent that such functions can operate far faster than they do in our one millisecond-scale brains, we'll see an aspect of 'superhuman' emerging from the 'work-alike'" (p 2).

Freeman Dyson is widely respected for his contributions to astrophysics, his work on behalf of nuclear weapons control, and his broader interest in the human prospect. He offers this vision of the human future:

> "The next hundred years will be a transition between the metal-and-silicon technology of today and the enzyme-and-nerve technology of tomorrow..., the result of combining the tools of genetic engineering and artificial intelligence. [This will be followed by] the permanent and irrevocable expansion of life's habitat from Earth into the cosmos…To this process of growth and diversification I see no end." (1988 pp 286; 298)

Finally, Stephen Hawking, whom many regard as the most important physicist since Albert Einstein, believes that in the future, "Humans will change their genetic make-up to give them more intelligence and better memory." According to an interviewer,

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[8] Tipler shared this story during a symposium at U.C. Berkeley in April 1995.

> "Hawking believes some life form could be designed to withstand the hundreds of thousands of years it would take to travel around the galaxy. He even talks about a new kind of life – machines that could replicate themselves and populate far-off planets." (Einstein, 1996)

There are other explanations to account for what might appear to many to be a series of bizarre, even perverse, notions. One is that these authors, despite their intellectual gifts, may in some sense be mentally disturbed. For example, similar fantasies of omniscience, omnipotence and omnicompetence are frequently found among persons with narcissistic personalities and similar disorders.

Another possible explanation is that the Extraordinary Future is a narrative of denial that allows privileged persons a way to avoid confronting inequity, and social and political conflict in general, in the world. Distributional conflict can be mitigated so long as economic output continues to grow, but continued output growth depends upon continued technological innovation. If we can believe in a future of unending technological innovation we can more easily avoid having to worry about distributional concerns.[9]

Still another possibility is that the authors noted above may be right. Their analytic gifts may have enabled them to understand human nature, and the human predicament, more deeply than others have, and to envision a means by which we might transcend our plight and realize a more desirable future for all.

It is difficult to assess degrees of subjective development, denial or understanding, but perhaps we can assess objective credibility. How do the claims of the Extraordinary Future hold up under informed expert scrutiny?

Skeptical assessments of the vision of the Extraordinary Future are noted in **IIE-16**, along with responses. A tentative conclusion is that many of the more dramatic claims may indeed be

[9] The narrative of the Singularity might be thought of as a hypertrophied version of this dodge. If we believe that the confluence of near-future technological breakthroughs renders speculation beyond the next thirty to forty years or so irrelevant, then we are relieved of having to concern ourselves with much of anything.

BOX IIE-16. Skepticism Regarding the Extraordinary Future

Are the technologies of the Extraordinary Future credible? Some scientists have doubts.

1. Nanotechnology: The core of the nanotech vision is the "assembler", a machine of nano-scale dimensions that can be programmed to construct artifacts atom-by-atom, and to reproduce itself. Critics have suggested that quantum uncertainties, thermal vibration, and ambient high-energy radiation preclude such devices. Other critics charge that Drexler and others have overlooked crucial design requirements. Jones (in Stix, 1996) asks, "How do the assemblers get their information about which atom is where, in order to recognize and seize it? How do they know where they themselves are, so as to navigate from the supply dump (where raw atomic material is stored) to the correct position in which to place it? How will they get their power for comminution (breaking up material) into single atoms, navigation and, above all, for massive internal computing?…Until these [and other] questions are properly formulated and answered, nanotechnology need not be taken seriously." Other authors accuse nanotechnology of being a "cargo cult science", a disciple which has much of the trappings of real science but is founded on a gross illusion. (Stix, 1996). Proponents of nanotechnology offer detailed rebuttals. They note that quantum uncertainties apply to electrons but not to atoms and molecules. Damage from thermal vibration and ambient radiation could be controlled by the inclusion of mechanisms that detect, repair and replace damaged parts, in the same manner as does DNA. Energy could be supplied to assemblers via sound waves. A debate concerning the technical credibility of nanotechnology ensued in 1996 following a critical article in *Scientific American*. See details at www.foresight.org/SciAmDebate.

2. Intelligent machines: The construction of "intelligent" machines is central to the vision of the Extraordinary Future. The belief that this feasible is generally grounded in an existence proof: *we* are intelligent, and we are, in the final analysis, task-achieving systems constructed of matter and powered by energy, i.e., machines. Surprisingly, scientists and philosophers who are skeptical of the claims of the AI enthusiasts tend not to disagree with the substance of this argument. Rather, they emphasize the practical difficulty of achieving true artificial intelligence. Searle (1992) makes a strong case that digital computers cannot be "intentional," although he allows that intentional machines may be constructed in some other manner. Edleman (1992) doubts that artificial consciousness is likely to happen "for a very long time." He believes that artificial consciousness, like human consciousness, would have to evolve in a social milieu.

3. Immortality: The achievement of radical longevity would need to overcome the two related but different processes of cellular aging and cellular senescence. Aging is the result of wear and tear, largely caused by the progressive destruction of cellular components by free oxygen radicals that are a product of respiration. Cellular senescence is the inability of cells to undergo further division. This happens because the tips of DNA chains, called telomeres, shorten every time a cell divides, and are only long enough to allow 60-100 divisions. A program of radical longevity would require technology that could 1) manipulate DNA to allow telomeres to regenerate themselves and thus avoid senescence, 2) improve the cellular machinery that reduces the production of free radicals and improves repair capability, and 3) modify nerve cells so that they can reproduce and thus prevent the brain from shrinking. In

(more…)

Box IIE-16 (cont'd)

addition, any effective program of radical longevity should provide an improved immune system and high-powered medical care. Paul and Cox (1996) describe such a suite of such technologies and say, "actuarial calculations suggest that the expected life span of a non-aging, disease-free person who does not do anything stupid and who lives in a low crime area will be on the order of 1000 years." (p 295)

Skeptics suggest that the mechanisms of aging and death are evolutionary adaptations that are far more deeply embedded that the above program suggests. They argue that since animals are likely to die from disease, accident or predation after some expected period, animals that reproduced at a greater rate in their early years and then died would leave more offspring than those that might have given birth at a more leisurely pace spread over a longer possible biological lifespan, even if the biologically maximum possible number of offspring was significantly greater in the latter instance. Once the feature of natural death evolved, it would be adaptive for all other systems in a body to forego characteristics that would maintain their viability for longer than the average life-span. Thus any program that sought to extend longevity much beyond 100 years or so would likely require the massive re-engineering of numerous physiological processes. Proponents of life extension argue that these objections do not invalidate the legitimacy of their efforts. (see *The Economist*, 1995).

4. Human travel in space: Some proponents of the Extraordinary Future are also strong skeptics concerning the prospects for extensive human space travel. Paul and Cox (1996) say, "Bluntly put, people in space is a joke. It will never happen… Man in space is the evolutionary equivalent of fish conquering the land by building fish tanks with wheels." They describe the immense logistic, technical and environmental difficulties of planetary settlement and the effective impossibility of human interstellar travel. The Solar System might offer an exciting locale for scientific exploration but little else. Cox and Paul use this argument to support their case for the machine embodiment of consciousness, which could indeed allow interstellar travel. However, it is possible to offer a compromise assessment of the possibilities of humans in space. While interstellar travel is probably impossible, and extensive, permanent interplanetary settlements and Dyson Spheres may be impractical, the large-scale utilization of Solar System resources, using very advanced, highly reliable machines, tended by a limited technical staff, could still become an important human project over the next century.

highly problematic, but that a credible core remains. While ubiquitous Drexlerian nano-scale technologies may be beyond our reach, micro-scale technologies are not. Mental “uploading” may be a crackpot dream, but the enhancement of mental abilities via pharmaceuticals could become routine. The end of aging may be too much to expect, but healthy lifetimes lasting many more than seven or eight decades could be the norm for the grandchildren of children living today. And while the idea of the Singularity is likely an escapist fantasy, the suggestion that the emerging technologies are likely to enhance, rather than to exhaust, the potential for additional and even more profound technologies seems reasonable.

In short, we can’t assume that the vision of the Extraordinary Future is simply too outlandish to take seriously. Note also that the comparatively moderate technological project outlined by Coates’ et al. for 2025 lays precisely the groundwork needed to realize the technologies of the Extraordinary Future in the second half of the next century.

Discussion

Scenarios of Green sustainability, social-democratic internationalism and civilization-of-civilizations all affirm communal values that both support and constrain individual actions. But the current trajectory of technological change on balance tends to erode communal resources of allegiance, competence and power, and strengthens those effected through individuals, transient networks of individuals, and the narrowly instrumental institutions of corporate capitalism. These are the primary institutions of agency of techno-global neoliberalism.

The challenge to our new candidate advocated scenario—quantitative Scenario 3 and the narrative scenario of social democratic internationalism—is particularly acute. It’s difficult not to come away from a close reading of Coates’ list with the sense that even under a strong social democratic internationalist regime, the great majority of the technologies listed would, in themselves, be deemed acceptable--in fact, desirable. The core social democratic ethos would mandate that the benefits of such technologies be equitably distributed, but would not, in most instances, demand that they be foregone. With respect to ecological integrity, assessment is more complex. Coates et al. put a high priority on environmental protection, but it is a very high-tech, deeply managed form of environmental protection that they call for. It would, however, be a viable option under many variants of social democracy. On the other hand, a social-democratic environmentalism informed more heavily by some of the values of Green sustainability would not be as ready as Coates' account suggests, perhaps, to genetically engineer or otherwise technologically manipulate forests, crops, livestock, fisheries and human beings.

But with the exception of genetic engineering, I don't have the sense that the technological "look and feel" of a social democratic internationalist world would necessarily be *radically* different from what it would be under techno-global neoliberalism. Arguably it might in many ways be even more technologically dense, simply because on a global scale economic output grows *faster* under the social democratic internationalist Scenario 3 than it does under the business-as-usual/neo-liberal Scenario 1.[10]

It is possible that a markedly less technologically dense 21st century might come about if certain of the voluntary simplicity sensibilities described in Section II.C.3 were to become rooted and widespread within an otherwise social-democratic/Scenario 3 trajectory. We might imagine a world that still grows steadily along the Scenario 3 trajectory, and is economically prosperous and technologically rich, but which has come to use technology in a more subtle, discreet and non-invasive manner than at present.

What might be the motivation for such restraint? For one thing, such a soft-path techno-cultural trajectory would be consistent with the element in Scenario 3 that calls for per capita GDP growth rates to lessen significantly in the developed world by the middle of the next century, and in the rest of the world after another hundred years. Beyond this, however, I believe that the vision of the Extraordinary Future itself, as proclaimed by its enthusiasts, would strike the

[10] Although economic growth is slower in the developed countries under Scenario 3 than under Scenario 1, it is faster in the developing countries. This makes global economic growth on balance, faster. See the scenario displays in Section I.A.3.

great number of people who appreciate its implications as sufficient reason to adopt an attitude of extreme caution regarding the new technologies. After all, it is not a trivial matter when a reputable scientist proclaims that "it is a logically necessary consequence of eternal progress that our species become extinct."[11]

Concern about the impacts of technology is hardly new. What is different now is simply that the stakes are quickly getting much larger than ever before. Profoundly powerful technologies are being developed at the same historical moment that globalization is making their control more difficult. The possibility of a run-away prisoners' dilemma presents itself, in which the judgment by individuals that they will be unable to count on societal control of destabilizing technologies leads them to behave in ways that accelerate the spread of the destabilizing technologies themselves.

The general outlines of what needs to be done should be clear. We need to adopt a strong precautionary attitude about certain categories of new technological innovations; we need to reaffirm the right and responsibility of governments and civil society to constrain technological innovations judged to be undesirable; and we need to establish the national and international institutions and policies needed to enforce such constraints.

The major technological challenge

Of all the sets of technologies noted in our discussion thus far there is one that stands out as uniquely problematic. These are the new human genetic and reproductive technologies. These technologies figure prominently in popular fears about the human future, and do so in ways that computers and space travel, for example, do not. Together with "artificial intelligence" and "artificial life," they are the centerpiece technologies of the techno-utopian world view. [12]

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[11] Tipler, quoted above.

[12] Our ability to genetically engineer animals is a near existence proof of our ability to genetically engineer human beings, and the creation of metabolizing, reproducing structures – "artificial life" - is actively being pursued. But I follow those authors who believe that "artificial intelligence" will not be possible. For discussion see Searle (1992), Chalmers (1996), McGinn (1991), and Nagle (1974). For a detailed review of

The new human genetic technologies have a uniquely powerful and transformative potential, one which could set humankind on a trajectory that would make it greatly more difficult, and eventually impossible, to affirm communal goals of a global nature. If widely applied to the modification of existing human attributes in ways that can be passed on to our children, these technologies would erode our experience of being part of a common humanity, both within and across generations. Inheritable genetic modification of human biological and cognitive traits would set into motion a positive feedback loop generating increasingly more profound modifications. Each generation of genetically modified people would be less indisposed towards, and have more capability for, modification of their own children. Indeed, such concepts as "generation" and even "children" would change, as the biological relationships with specific others that have defined those categories become less central to ones' identity. The fund of conceptual categories and processes bequeathed to us by natural selection over millennia would now be instantly mutable. How would a person whose mental processes in part derive from purposeful genetic modification think about what it would be like *not* to have genetically modified mental processes?

It can be argued that in a world of many billions of people many decades would pass before even a small percent of humanity is genetically modified. This may be so, but the point offers little comfort. Well before such technologies become widely adopted, the mere *expectation* that they will in due course be widely used will begin to change the way we think of ourselves, our children, and our obligations to others. It would set off a techno-eugenic arms race as individuals and countries compete to develop and apply the latest genetic enhancements.

Such a prospect is deeply antithetical to any vision of a social democratic internationalist / Scenario 3 world. If we are to have any hope of achieving such a world, human genetic

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the "consciousness wars" see *The Nature of Consciousness* (Block et al, 1997). On the other hand, the inheritable modification of cognitive processes through genetic engineering could be practicable within two decades or less.

technologies will need to be strongly controlled, and in importance instances proscribed. In the next section we explore in detail the challenges that the new human genetic technologies present.