

Technology's Promise

Highlights from the TechCast Project

By William E. Halal



PHOTO ILLUSTRATION: C.G.WAGNER / WFS

An ongoing study of technology forecasts by leading experts shows promising breakthroughs in energy, information technology, health care, transportation, and other critical fields.

Rapid advances in information systems are driving breakthroughs in all scientific fields. The decoding of the human genome, for instance, was made possible by the collective use of a dozen supercomputers to decipher the 3 billion bits of information stored in DNA. For the first time in history, knowledge—the very heart of scientific progress—is being harnessed systematically on a massive scale.

That's why breakthroughs are appearing everywhere. We can now realistically envision fuel cells that replace oil with hydrogen, medical control over the genetic process of life itself, computer power becoming cheap and infinite, mobile communications at lightning speeds, robots serving as helpers and caregivers, and much, much more to come.



Hybrid solar lighting technology researchers Alex Fischer (left) and Jeff Muhs of Oak Ridge National Laboratory.

are immediate enough to take seriously. These are the breakthroughs most likely to affect you and your organization.

Energy and Environment

- **Alternative energy.** Global oil production may be peaking at a time when developing nations are starting to use more oil and when concern over the environment is growing, signaling the end of a long era dominated by carbon fuels. Wind power is experiencing a surge of growth because it is now competitive; solar and biomass energies are almost competitive, and nuclear power is seeing renewed interest. Conservation also remains a strong option in the alternative energy picture.

A hydrogen economy is possible in the long term, with potential use of hydrogen as a means of storing, carrying, and delivering energy. Alternatives now comprise about 17% of global energy use and are growing by 30% per year, backed by wide public support and corporate investment. As oil prices continue to rise and the cost of alternatives falls, carbon fuels will no longer be the main energy source in two to three decades. TechCast projects 2020 (plus or minus five years) as the

continued on page 4

Forecasting breakthroughs that span the entire spectrum of science and technology is the daunting challenge of a major forecasting project conducted over the past decade at George Washington University and my company, TechCast LLC. Working online through a sophisticated Web site (www.TechCast.org), we pool the knowledge of 100 high-tech executives, scientists, engineers, academics, consultants, futurists, and other leading experts around the world. And by cycling through this process every few months, we create a “learning system” for uncovering the best possible answers to tough questions.

The result is possibly the best forecast data ever assembled, based on trends that outline how the technology revolution is poised to transform life over the next 20 to 30 years.

Forecasts of the Technology Revolution

Figure 1 (page 43) summarizes the forecast results in seven major technology areas. The major conclusion of this work is that breakthroughs are occurring in all fields and will transform industries, the way organizations work, and society itself.

We also use bubble charts to illustrate all three types of data for each field, as shown below for all seven fields. What follows are highlights that strike me as especially interesting or strategic. These projections are for breakthroughs that may have profound scientific implications, big commercial potential, great social impacts, and high confidence, and

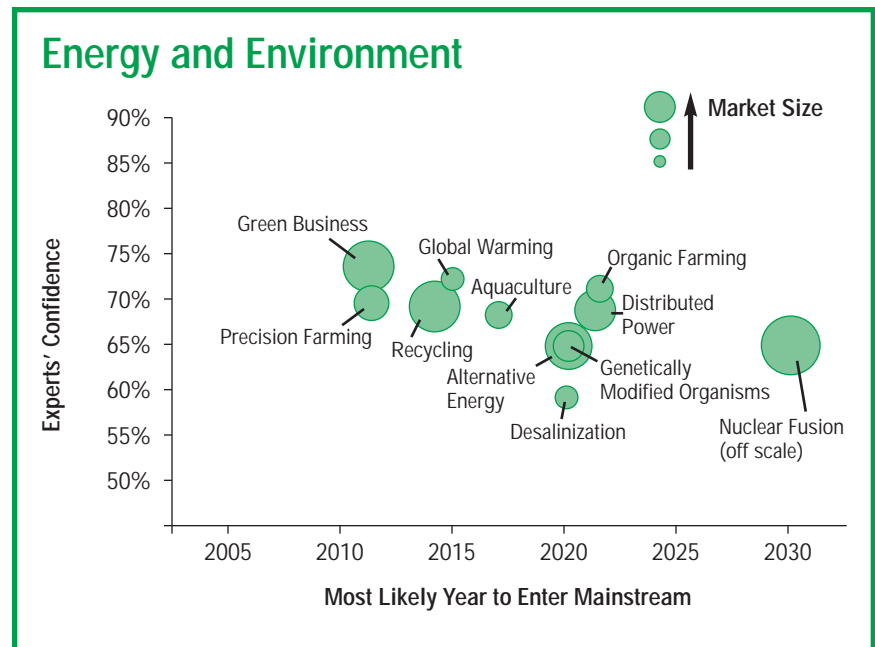
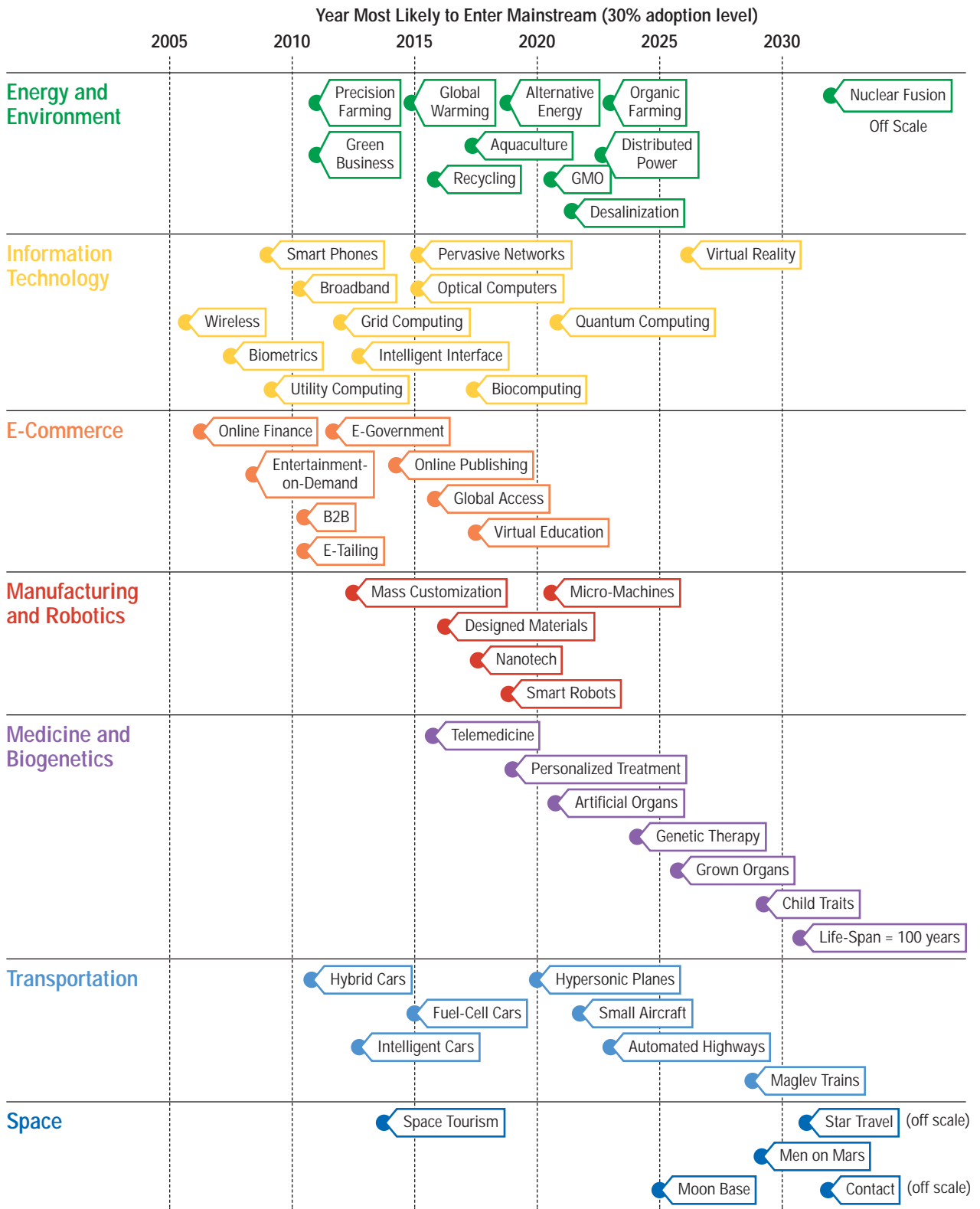


Figure 1. Technology Forecasts: From Promise to Mainstream



Source: TechCast, www.TechCast.org



GPS instruments assist in precision farming studies by U.S. Agricultural Research Service scientist Mike Schlemmer and colleagues.



IBM researcher Ronald Ridgeway examines new IBM computer with powerful Cell micro-processor, effectively a “supercomputer on a chip.”

continued from page 2

serious beginning of this transition, when 30% of global energy is likely to come from alternative sources.

- **Desalination.** The need for clean water is severe and growing in most parts of the world. One analyst said, “Water promises to be in the twenty-first century what oil was in the twentieth century.” Desalinated water was expensive but advanced technologies have reduced costs from \$20 per gallon in 1950 to now approaching 1¢ per gallon. Ovation Products, for instance, claims it can distill water contaminated with anything into pure drinking water for a penny a gallon. California is building 13 plants that could supply 10%–20% of the state’s water. Florida is building the largest in the Western Hemisphere, and Texas is planning nine plants. Israel has five large projects. We estimate desalination to become mainstream about 2020.

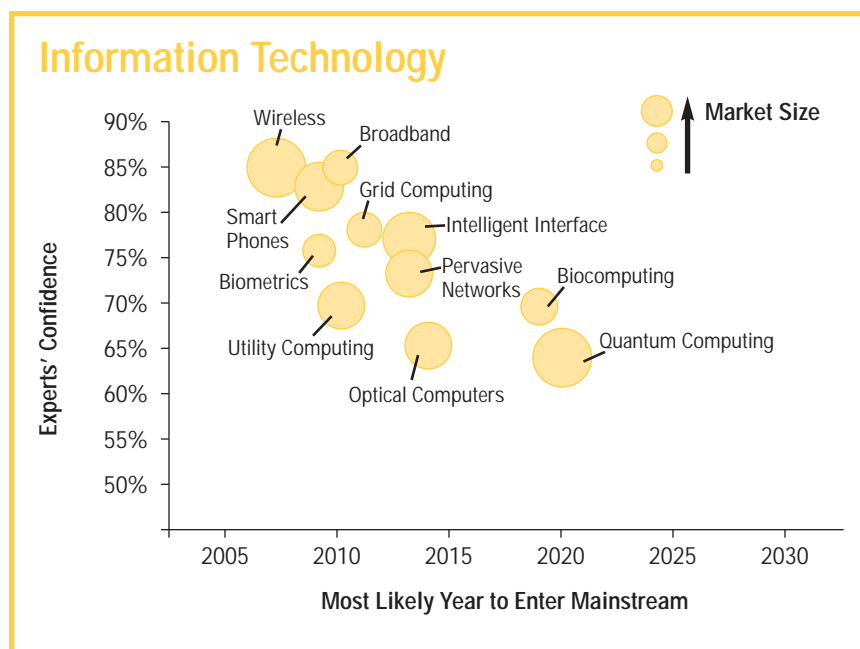
- **Precision farming.** Computerized control of irrigation, seed, fertilizer, and pesticides to suit variations in land involves onboard GPS, geographic information systems, and other forms of information technologies. Twenty percent of farmers in the United States are adopting these practices because precision farming reduces the need for harmful chemicals, raises yields, and protects the environment. A review of 108 stud-

ies found 63% of sites using these technologies were more profitable than those that did not. Predicted one farm equipment manufacturer, “In 10 years, every farmer will use this technology.” TechCast projects that precision farming will reach mainstream use by about 2010–2015.

Information Technology

- **Biometrics.** Viruses, hackers, spam, and identity theft are

increasing, and biometrics offer a possible solution. Fingerprints, hand geometry, the iris, voice, and facial features are all being used in identity verification systems by governments and corporations, with fingerprint recognition making up 67% of these applications. One TechCast participant described biometrics as a “killer application,” and another said that “the market is set to explode.” The technology is not perfect, but “multi-modal” systems combining two or



more techniques are almost fool-proof. TechCast forecasts most security systems will primarily use biometrics by about 2010, plus or minus two years.

- **Quantum computers.** The strange behavior of matter at the quantum level makes this computational technique bizarre. The basic unit of quantum computing is a “qubit”—an electron spinning either clockwise or counterclockwise, representing a 0 or a 1. Because electrons can coexist in two places simultaneously, a single electron can carry two qubits, two electrons can produce four qubits, three electrons eight, and 20 electrons could perform a million computations. This exponential growth raises the hope of infinite processing power. A quantum computer could easily complete in seconds a task that would take a silicon computer billions of years. The first research prototypes are now running at Harvard University, the National Security Agency, and the Federal Reserve. Some TechCast experts are doubtful about the short-term prospects for breakthroughs because of the uncertainty surrounding the heroic task of harnessing data at the quantum level. Our best forecast is that quantum computers could become available commercially about 2021, plus or minus five years.

E-Commerce

- **Entertainment-on-demand.** Digital downloading of music, video, games, and other consumer entertainment has grown with the introduction of platforms and portable players such as Apple’s iTunes and iPod system. BitTorrent is organizing the entertainment industry to deliver movies and TV shows online. Turner Entertainment is using holographic discs to store movies. Digital TV, DVD players/recorders, TiVo, wireless hubs, large flat screens, and other innovations are converging toward the creation of a “digital home.” Great obstacles remain, but the inexorable advance of IT makes this huge application almost inevitable. A Forrester analyst said, “Once customers try online entertainment, they’ll never go back.”



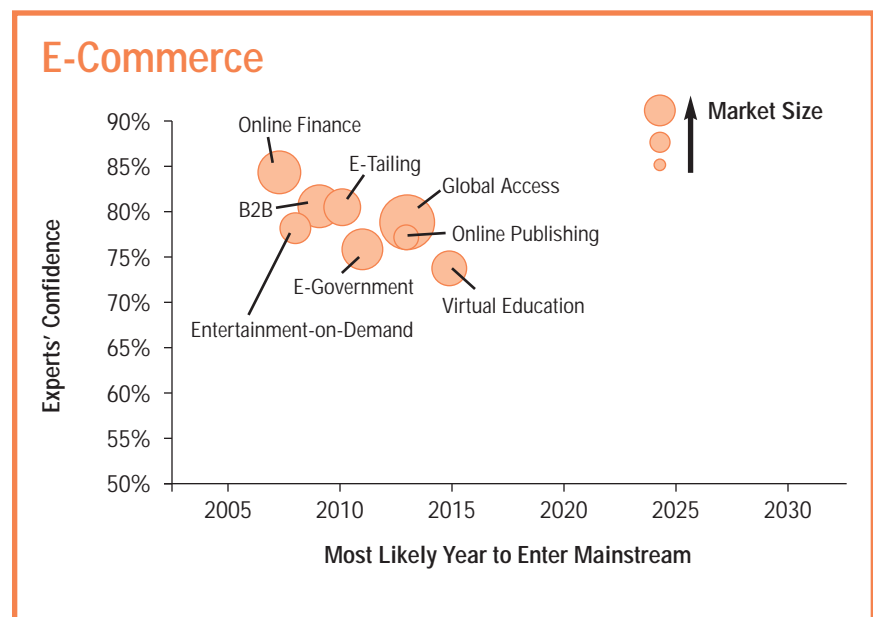
Apple Computer’s popular iPod Nano brings users portable entertainment-on-demand.

TechCast estimates 30% adoption levels by 2008.

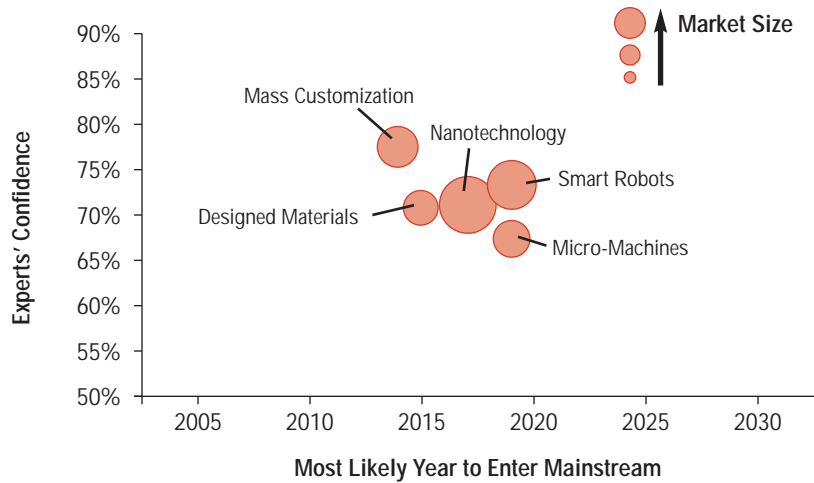
- **Global access.** The challenge of bringing modern communications media to poor nations is enormous, but lower-cost technologies are relentlessly connecting the globe. Wireless is especially promising because it is cheap and requires little infrastructure. The old view of the world’s poor being a burden has shifted to seeing them as a huge new market. Tech developers, entre-

preneurs, and philanthropists such as MIT, AMD, Dell, Hewlett-Packard, and Intel are partnering to jump-start the poor into the Information Age. India alone now has 250 million middle-class people using IT, and there are a similar number in China. TechCast estimates 30% of the world population will have access to telephones, TV, Internet, and other forms of IT by 2016.

- **Virtual education (VE), or distance learning,** makes sense because



Manufacturing and Robotics



that virtual education will enter mainstream use about 2015.

Manufacturing and Robotics

- Nanotechnology.** The “nanosphere” consists of objects measured in one billionth of a meter, and revolutionary research is giving us greater control over this tiny world. Matter behaves differently at the nano level: Electricity flows more easily, and materials change properties. The imminent possibility of creating more-powerful computers, medical treatments, and virtually any type of extraordinary item from scratch now has the entire world excited, with billions of dollars invested in research that produces breakthroughs daily. TechCast projects that nanotechnology applications will likely reach mainstream use by about 2015, but there is a wide variation in this forecast among the panel, ranging from 2010 to 2020. The potential market is vast, in the trillion-dollar range.

- Smart robots.** Intelligent robots are rapidly being developed that walk and climb stairs, speak with humans, and perform complex tasks. As computer power, artificial intelligence, and other enabling technologies mature, smart robots are ex-

education is basically a knowledge transferring process, but only 10% of higher education is conducted online. Reasons: Teachers resist changes in their traditional methods, it is hard to convey complex ideas virtually, and costs usually exceed revenues. Improvements in technology

and instructional methods are allowing some institutions to thrive with online courses, and 100 million Americans take continuing education, the prime target. E-Training now accounts for about 30% of corporate training and is expected to exceed 50% soon. TechCast projects

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Lt. Colonel Andrew Lourake is the first above-the-knee amputee to return to flying status in the history of the U.S. Department of Defense, thanks to advances in creation of artificial body parts.

ORNL

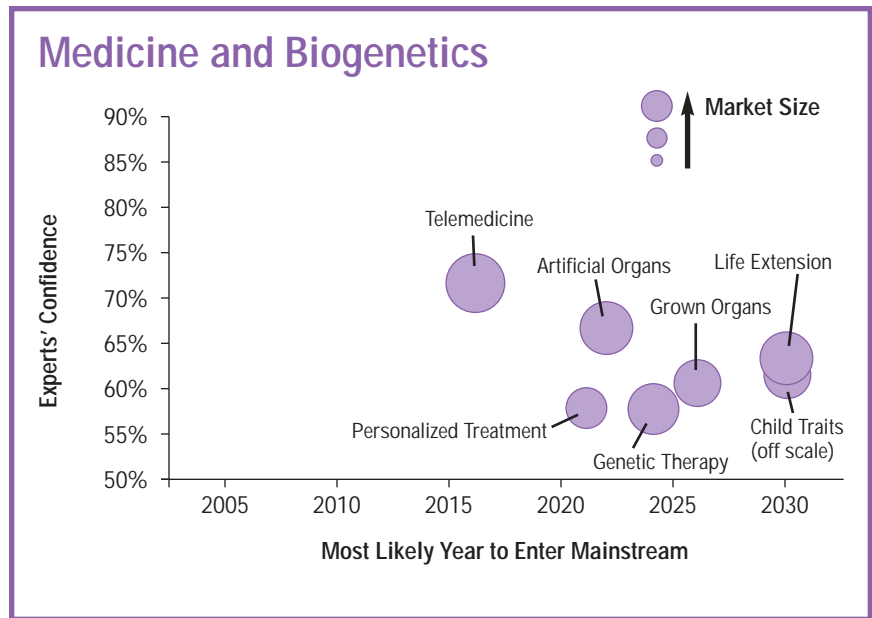


Micro-robot, a battery-powered sensor developed at Oak Ridge National Laboratory, works as a miniature mobile detector of chemical and biological agents.

pected to soon create a new era of affordable and convenient helpers. The Japanese and Koreans are now gearing up to sell millions of robots to serve important roles in industrial work, home services, health care, military, and leisure activities. They intend to start placing robots in homes by 2010, breaching the critical boundary between humans and machine in ways unimaginable today, much as the World Wide Web did 10 years ago. TechCast estimates robot use is likely to reach the mainstream about 2020, possibly earlier.

Medicine and Biogenetics

- **Artificial organs.** An astonishing array of body parts can now be replaced with artificial equivalents: skin, bone, blood vessels, cochlea, heart valves, joints, and so on. Using a combination of computer chips, micromachines, tissue engineering, and other new technologies, bionic parts may soon be available to replace the entire human body. Artificial arms and legs use chips to coordinate movements, are wired into the nervous system so they can be controlled by normal thought, use sensors to feel touch, and have micromotors to power joints. Researchers have even placed small video camera systems in eyeglasses



to restore sight. TechCast estimates artificial organs will replace major body parts by about 2022, plus or minus four years.

- **Telemedicine.** Medicine is probably the least computerized industry in the world, which suggests enormous possibilities for improvement. Health care is a very complex field, which partly explains the problem, but it is also stalled by resistance of physicians and hospital administrators. More-powerful IT systems could help reduce the skyrocketing

costs of treatment, however, so progressive hospitals are embracing such technologies as online medical records, computerized diagnostics, virtual exams with your physician, and a host of other forms of telemedicine. TechCast projects that these advances could enter the mainstream by about 2015, saving hundreds of billions of dollars, greatly improving health care, and providing more convenient service.

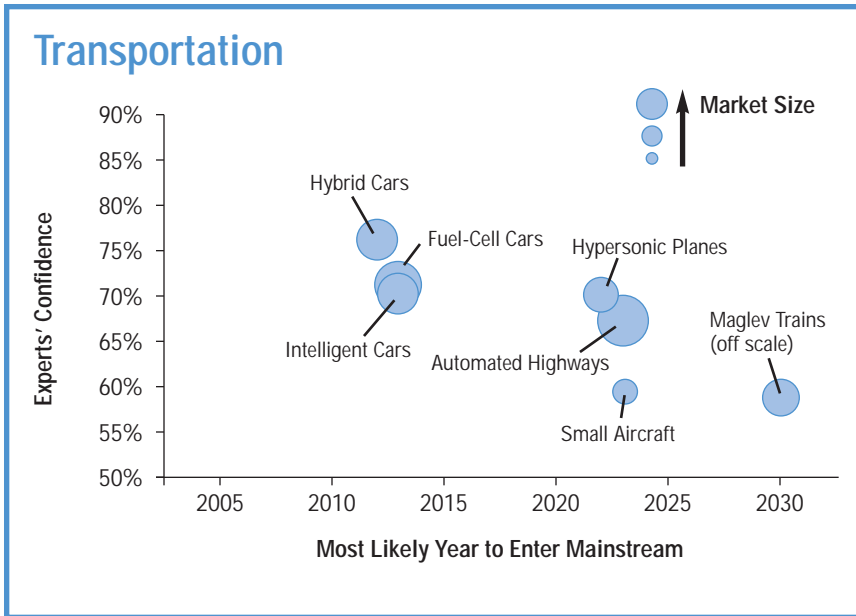
- **Cancer cure.** After decades of limited progress, smarter drugs, nanotechnology, and molecular biology are producing far more sophisticated treatments that are selective, noninvasive, and safe. Nanotech agents are especially promising because they are intelligent enough to seek out cancer cells, small enough to enter cells and destroy them, and safely removable by the kidneys. TechCast's experts think it will become common for cancer patients to recover to lead full lives by about 2023, plus or minus five years.

- **Life extension.** Opinions on aging are controversial, but the evidence is accumulating that human life extension is possible. Discoveries are being made in extending the life of cells, repairing damage to the body, replacing organs, curing major illnesses, and improving lifestyles. As a result, trends suggest that human life-spans could approach what seems the natural limit of 120

DIANE A. REID / NATIONAL CANCER INSTITUTE



Cancer researcher prepares well cell culture plates for centrifuge. New technologies are rapidly advancing cancer detection and treatment.



years. The challenges and social consequences are enormous, but many authorities are confident the problems can be solved. TechCast's data suggest life-spans could average 100 years by about 2030.

Transportation

- Hybrid/fuel-cell cars.** Under the leadership of Japanese carmakers, hybrids represent a highly promising alternative to the conventional internal combustion engine. To achieve highest possible efficiency, hybrid autos are powered alternately by a small gasoline engine at high speeds and by a battery at lower speeds. This is not only more efficient, but also reduces pollution. Diesel engines may even work better, and fuel-cell versions are coming soon. All these designs use electric motors to drive wheels, the battery to store energy, and regenerative braking (feeding the braking energy back into the battery) to conserve it. New, lighter materials for the bodies of the vehicles will add more efficiency in future vehicles' performance. If present indications hold and improvements are made in cost, TechCast estimates 30% adoption of hybrids by 2012–2018, and fuel-cell cars a few years later.

- Automated highways.** With no end in sight to mounting traffic congestion, automated highways offer a

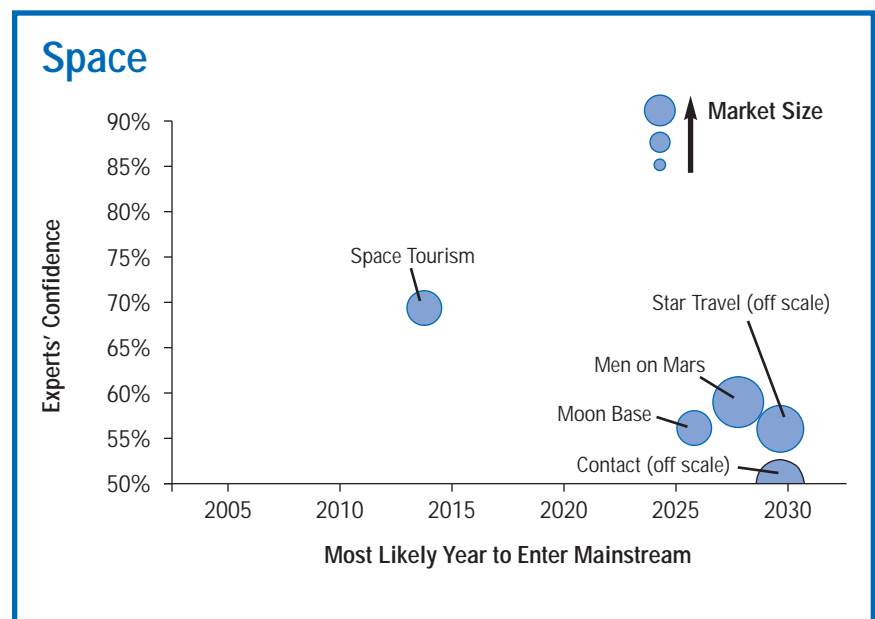
far less costly, faster, and safer way to travel than building more roads. Computer models indicate automation would double or triple highway capacity, and it costs less than \$10,000 per mile, compared with \$1 million to \$100 million per mile of new highway. Carmakers are starting to incorporate collision avoidance radar, cruise control, and other electronic systems into "intelligent cars," which could fit nicely into automated highway systems. Vehicles would be equipped with sensors and wireless communications to

control speed, steering, and braking on electronically equipped lanes, spaced at close intervals to form small convoys or platoons. General Motors has tested driverless cars traveling at 70 mph bumper-to-bumper. TechCast estimates 30% of highway traffic will flow on automated roadways by 2025, plus or minus five years.

- Hypersonic planes.** The French-British Concorde may be passé, but the prospect of hypersonic flight is alive and well as globalization drives increased travel across the world. The new generation of hypersonic planes incorporates lightweight airframes and highly reliable scramjet engines, which suck in oxygen from the thin atmosphere at high speeds. Governments and corporations are gearing up to deliver these vehicles over the next decade or two, making it possible to reduce flying time from the Eastern U.S. to Asia from 30 hours to three hours. Space agencies and commercial ventures in Russia, Australia, and the United States are successfully testing planes flying at Mach 10. TechCast experts think hypersonic planes are likely to be used for 30% of long flights by 2020.

Space

- Space tourism.** The idea seemed silly at first, but now that private vehicles have traveled into space, it is





Commercial spaceport built in the United Arab Emirates by Space Adventures, the first company to send tourists into outer space.

suddenly almost certain that more will follow. Interest in space tourism is strong and costs should fall by 90% as space travel privatizes. According to Peter Diamandis, who funded the \$10 million X Prize won by Burt Rutan's *SpaceShip One*, "We're on the verge of the golden age in space. It should soon be possible to tour space on a routine basis." Private launch facilities are being planned in New Mexico, Oklahoma, and Texas, and companies are planning tourist trips. The New Mexico facility has signed a \$225 million contract to support Virgin Galactic, Richard Branson's new venture that has thousands of clients eager to take suborbital flights for \$200,000. TechCast thinks we should see the first space cruiser fly 50–100 miles above Earth sometime around 2014.

- **Moon colony and humans on Mars.** The Moon is a convenient launching pad into space, as it is close, easy to escape its mild gravity, and has everything needed for space ventures, including water. The challenges of building and maintaining a permanent lunar base are daunting, but not worse than the International Space Station, which has been inhabited for years.

The Moon is likely to serve as part of the more ambitious attempt to

land humans on Mars in the next two decades or so. Mars is so far away that it would take a full year for a round trip, requiring sophisticated life-support systems, nuclear engines to make the journey, and serious precautions to protect astronauts from radiation. Still, the symbolic allure of sending humans to the red planet is hard to resist, and progress is leading in this direction. TechCast believes that the two missions are likely to be accomplished about 2025.

Technology's Promise

The above results are just a small sampling of the wealth of data accumulated on the TechCast project's Web site.

Although some of these technologies may not work out, most are likely to arrive roughly as forecast. It would be wise to start planning for this wave of technological change that will threaten the creative destruction of existing markets, alter the way people work, reshape lifestyles, and restructure the world itself. There may be uncertainty about specific breakthroughs, but there is very little uncertainty that we are going to see plenty of technological change over the next few decades.

The following scenarios offer a quick view of how these innovations will likely evolve.

2010: Intelligence. The remainder of this decade is likely to focus on intelligent advances in information systems and e-commerce. The world in 2010 is almost certain to be smarter, faster, and more fully connected, setting the stage for the breakthroughs to come.

2020: Breakthrough. This decisive time period should see computing power match the human brain, enabling artificial intelligence to permeate our environment. The ensuing capabilities in smart robots, speech recognition, intelligent agents, and other uses that can only be imagined should permit huge advances in telemedicine, virtual education, e-government, and all other facets of life.

2030: Challenge. Industrialization will reach most developing nations at this point, with as many as 5 to 7 billion people living in industrialized societies. The next generation of quantum/optical computing should emerge, as well as advanced health care using genetic engineering. Although technological powers will be vast, they will not be a panacea for society's ongoing problems. Intercultural conflict, weapons of mass destruction, and threats of environmental collapse are likely to force the move to some form of global community as the best means for managing such nagging problems.

TechCast has done a lot of work on this pivotal issue. We define it in terms of institutional change, and we are considering an entire new field to forecast breakthroughs in *social technology*, such as the *collaborative/quasi-democratic corporation*, *self-organizing* business firms and governments, and *technologies of consciousness*.

2040–2050: Maturity. Civilization has withstood the fall of Rome, World Wars I and II, and threats of nuclear holocaust. It will probably survive globalization, mainly because this is a historic, evolutionary process beyond anything we can control. TechCast's forecasts suggest the challenges facing globalization are likely to be resolved into a fully modernized, fairly harmonious



TechCast's Online Research Method

The TechCast system is an improved version of the Delphi method that incorporates background information to assist experts in reaching more precise estimates of what breakthroughs may occur and when they may achieve specific milestones or benchmarks. We scan the scientific literature, media, Internet, and other sources, and we organize this data into a "breakthrough analysis" consisting of trends opposing and driving each technology. "Events" or "milestones" are defined as adoption levels to be forecast. We usually use the 30% adoption level, but others are used where appropriate. The 30% level is of particular interest because emerging technologies usually enter the mainstream at this point.

The experts work online to integrate all this information into accurate estimates. We strive to enlist the most competent authorities with advanced degrees, extensive publications, and relevant experience. Experts are asked to focus on

areas where they are most knowledgeable, so not all respond to all technologies.

The system automatically aggregates estimates to forecast the "Most Likely Year" each technology will reach its adoption level, the "Experts' Confidence" in this forecast, and the likely "Market Size." Delphi studies are considered reliable if they include a dozen or more experts, and these results surpass that criterion considerably, running about 50 or more data sets. The results are fed back to experts, and this process is repeated every year or so to track forecasts over time, allowing us to extrapolate the best possible forecast.

The obvious question raised by forecasts is, "How accurate are the results?" TechCast has been using this method for 15 years on a variety of projects, and the results show that variation among forecasts averages a margin of error of three years. We have also recorded "arrivals" of several technologies roughly within this same three-

year error margin. These results are especially compelling since the expert panel changed over this time, as did the prospects for various technologies.

Some contend that expert judgment is subjective, whereas quantitative forecasts are precise. But quantitative methods also involve large amounts of uncertainty because of underlying assumptions. The TechCast approach is superior because it subsumes quantitative forecasts into the analyses provided to experts and then allows their considered judgment to resolve the uncertainty that remains. Experts may have their own biases, naturally, but they usually balance each other out in the aggregate results. We have found through experience that this process reduces uncertainty to about 20%–30%. The outcome can be seen as good enough to get decision makers into the right ballpark, as one participant put it.

—William E. Halal

globe, somewhat like a far larger and more diverse version of the United States or European Union. Scientists think of this as reaching a "Type 1 Civilization"—a unified planet. Local wars, ecological disasters, and other mishaps will continue, of course, but limited to the normal dysfunctions of any social system.

Cutting across the scenarios allows us to trace the larger path of civilization's progress. The earlier phases—agriculture, manufacturing, services—have been completed in modern nations, and we are now passing rapidly through the information/knowledge phase. Note that the bubbles stop at about 2020 in the chart on Information Technology, raising the tantalizing question: What follows the Information Age?

Everything I know tells me the next stage will focus on a global community inspired by higher levels of consciousness. It's the next logical step "beyond knowledge." This hardly means it will be a utopia, but with a modicum of hard work, wisdom, and luck, this wave of innovative technological change promises to produce some form of coherent global order focusing on higher-order, transformational goals by about 2040–2050, possibly sooner.

I realize this may seem too good to be true, especially because futurists tend to place such prospects in the distant future. We often fail to recognize that the power of knowledge is now accelerating advances as never before. Life-extension technologies should raise average life-spans to 100 years about 2030, so a 50-year-old today is very likely to witness this highpoint in civilization's advance at a youthful 85–95 years of age. Therefore, this is not merely an

intellectual exercise. Most of us will be fortunate enough to live through this coming unification of the globe. It could not happen soon enough. □



About the Author

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This article draws from drafts of his forthcoming book, *Technology's Promise: Expert Forecasts on the Coming Transformation of Business and Society* (London: Palgrave/Macmillan).

TechCast cordially invites serious participation by potential experts, subscribers, organizations seeking assistance, or sponsors wishing to support the project. Details: www.TechCast.org.

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