**14. Science and Technology**

**How can scientific and technological breakthroughs be accelerated to improve the human condition?**

The acceleration of S&T innovations from improved instrumentation, communications among scientists, and synergies among nanotechnology, biotechnology, information technology, cognitive science, and quantum technology continues to fundamentally change the prospects for civilization. Genetic code is being written to create new life forms such as plants that emit hydrogen instead of oxygen; the lab-created Isx-9 molecule can make nerve stem cells mature into brain cells, leading the way to brain regeneration; and other stem cell applications could revitalize any part of the body in the future. An olfactory sensor can detect the difference in odor between normal and cancerous cells. External light can be concentrated on internal targets for photodynamic therapy and to power implanted devices. Surgical robots are now used routinely in operations ranging from cardiothoracic surgery to urology; manufacturing robots are proliferating and may expand to agriculture and service jobs, freeing more humans to invent the future. Millions of people volunteer their computers’ excess capacity to help find cures for cancer.

An INTEL computer for NASA is expected to perform at 10 petaflops (1,000 trillion calculations per second) by 2012, and IBM has promised DOE a computer at 20 petaflops by 2011, which is estimated to be the speed of the human brain. Such supercomputers can be applied to simulations in medicine, materials, climate predictions, and nuclear tests. Scanning electron microscopes can see 0.01 nanometers (the distance between a hydrogen nucleus and its electron). Photons have been slowed and accelerated and four photons have been precisely controlled on a silicon chip to learn how to create optical computers. Quantum entanglement has been demonstrated over distances of 144 km. Experiments to teleport individual photons are being conducted. Synthetic chromosomes have been created from laboratory chemicals; the Large Hadron Collider was turned on for the first time to search for the Higgs boson; and the nature of dark energy that may accelerate the expansion of the universe is being explored to understand gravity. Over 350 planets have been discovered orbiting other stars.

Even though the global economy is slowing, Battelle forecasts global R&D for 2009 to be 3.2% higher than last year. Over 164,000 patents were filed in 2008. Over 600 nanotechnology-related products improve quality and make new capacities possible, from releasing medicine in the body to forming thin-film photovoltaics, promising to reduce cost, resource use, and pollution per unit of output. The market for nano-related products is expected to be $3 trillion by 2015.

Commercial services are now available to scan a client’s DNA for single nucleotide polymorphisms for fees ranging from $399 to $2,500. The price for a complete DNA scan is expected to drop to $100 and require only one day, opening the possibility of truly customized medicine. Genetic research seems destined to cure inherited disease potentials. New diseases like SARS can now have their DNA sequenced in several weeks, speeding cures for new infectious diseases. Human skin cells have been stimulated to act like embryonic stem cells; pancreatic tissue created from embryonic stem cells has generated insulin. Genetically modified viruses can coat themselves with electrically conducting metals to form nano-wires that self-assemble into battery components, and viruses have been used to help build efficient batteries that are half the size of a human cell. Some 70% of the DNA of an extinct mammoth has been sequenced.

MRI brain imaging shows primitive pictures of real-time thought processes. Nanoparticles and fibers stimulate neural growth, and mini-biocomputers help treat specific individual cells. Robotic micro-tweezers gently pick up and move single cells. Faint magnetic signals from a single electron buried inside a solid sample have been detected. Organic transistors with a single-molecule channel length are now visible.

Transistors measuring 10 by 1 atoms have been produced out of graphene, a material just one atom thick, the thinnest material in the world. Graphene may ultimately replace silicon in many nano-electronic applications. However, environmental health impact studies may find dangers and initiate regulations for nanotech production and use. A science roadmap has been produced for atomically precise nanoscale building blocks, components, and devices. Nanobots the size of blood cells may one day enter the body to diagnose and provide therapies and internal VR imagery.

Yet the risks from acceleration and globalization of S&T are enormous (see CD Chapter 3.5 for global 2025 S&T scenarios) and give rise to future ethical issues (see CD Chapter 5, Science and Technology Management Issues). We need a global collective intelligence system to track S&T advances, forecast consequences, and document a range of views so that politicians and the public can understand the potential consequences of new S&T. Currently the Inter Academy Panel, a worldwide network of 100 science academies, is increasing access to S&T information and cooperation around the world, and heads of government science information portals are beginning to collaborate to better inform the world public. Supporting basic science is necessary to replenish the pool of knowledge from which applied science draws its insights to improve the human condition.

Challenge 14 will have been addressed seriously when the funding of R&D for societal needs reaches parity with funding for weapons and when an international science and technology organization is established that routinely connects world S&T knowledge for use in R&D priority setting and legislation.

**Regional Considerations**  
  
**Africa:** Synergies among African and first world science organizations is being created by the New Partnership for Africa’s Development, the UN University, the UN Economic Commission for Africa, UNESCO, and others. Collaborators could make such collaboration more real. Africa has 83 engineers for every one million people, compared with 1,000 per million in the more developed world. A hydroponic demonstration plant in Cape Verde grows food with gravel substituted for soil and less water. African scientists are using grid computing to screen for new compounds useful in fighting malaria.  
  
**Asia and Oceania:** For the first time, a Chinese company, Huawei Technology Co., filed the greatest number of patent applications. Applications from the Republic of Korea grew 12% in 2008 and those from China by 11.9%. China has the second largest R&D system in the world next to the U.S. Japan has the highest R&D budget per GDP in the world at 3.2%, and South Korea’s R&D is growing rapidly. The U.S. and China are increasing S&T cooperation in energy and environment. There are more IT engineers in Bangalore than in Silicon Valley. Japan is leading the Strategic Program for Building an Asian Science and Technology Community.  
  
**Europe:** The EU plans to increase R&D expenditures to 3% of GDP by 2010 and to attract an additional 700,000 researchers. Russia has lost over 500,000 scientists over the last 15 years, but a reverse trend is beginning, salaries have increased, innovation is encouraged, and high-tech is being supported. Switzerland has the largest number of Nobel prizes, patents, and science citations per person in the world. Norway has created an underground seed repository for some 268,000 samples of different varieties.  
  
**Latin America:** University S&T courses could be required that focus on helping the poorest communities. The region averages 0.4% of GDP for S&T development but hopes to increase that to 3% by 2010 and should improve its public-private R&D long-term cooperation, regional research networks, national strategic R&D planning, basic research, S&T literacy of benefits and risks, and incentives for private investment in local R&D.

**North America:** President Obama has pledged that the United States will invest 3% of its GDP in R&D, the largest investment in R&D in the nation’s history. Each week the U.S. Patent Office makes about 3,500 new patents freely available online. MIT offers free online S&T courses. Prizes can speed the distribution of technology that benefits humanity, such as the Tech Awards from the Tech Museum in San Jose, California, or Richard Branson’s new prize for a plan to remove a billion tons of carbon dioxide a year, as can tech sports like MIT’s robot competitions.