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Global Technology Revolution 2020

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Purpose

The intention of this forward looking study was to inform the U.S. National Intelligence Council's 2020 project - www.dni.gov/nic/NIC_2020_project.html - and help provide U.S. policymakers with a view of how world developments could evolve, identifying opportunities and potentially negative developments that might warrant policy action.

Global Technology Developments

This technical foresight was intended to provide science and technology input to the U.S. National Intelligence Council's 2020 project, which considered a wide range of possible world developments, and their policy ramifications. It was an update and extension of the previous RAND report, *The Global Technology Revolution*, published in 2001, which provided the science and technology background for the National Intelligence Council's 2015 study.

Multiple-disciplinary Technologies Revolutionizing our Lives

In its previous foresight study, *The Global Technology Revolution*, RAND concluded that life in 2015 would be revolutionized by the growing effect of multidisciplinary technology across all dimensions of life: social, economic, political, and personal. This study had the objectives of extending the technology trend foresights to 2020, and probing deeper into the applications of emerging technologies, as well as their societal implications across the globe.

The following were some specific goals:

- Carry out detailed technology trend foresights in biotechnology, nanotechnology, information technology, and materials technology,
- Identify, based on these foresights, technology applications that were plausible by 2020 with potential for significant societal impact,
- Rank these technology applications based on technical feasibility, implementation feasibility, societal impact, and potential for global diffusion,
- Analyze international variations in the potential effects of these technology applications.

From Literature Review to Expert Judgement

This foresight study was based on a set of broad and deep reviews of the current research and development (R&D) literature and state-of-the-art carried out by technical area experts.

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These experts then identified plausible future technologies within a fifteen year time period that were based on an understanding of required technical developments, coupled with their judgments as to the feasibility of such developments.

Based on these technical foresights, the authors of the study identified **technology applications** - i.e., uses of future technologies that provide a desired function such as cheap solar energy or rural wireless communications. The authors then performed a rough net assessment of these technology applications according to:

- The number of **societal sectors** - water, food, land, population, governance, social structure, energy, health, economic development, education, defense/conflict, environment/pollution - that the technology application could impact,
- **Technical feasibility**, defined by the likelihood that a commercial product would be available based on this technology application by 2020,
- **Implementation feasibility**, defined by the rough size of the market that might exist for this technology application by 2020, and whether or not it raises public policy issues - e.g., ethical, privacy,
- Whether the technology application has the potential for **global diffusion**, or whether diffusion would be moderated because of appeal to limited economic, commercial, or social sectors, or countries or regions.

Technology Scan in 29 Countries

Finally, the authors defined **29 representative countries** around the world, and evaluated their human, physical, and institutional **capacity to acquire** a representative group of the top-ranked technology applications. The representative countries were selected for variation in size, region of the world, and socio-political conditions. The foresight experts then considered the **drivers** for and **barriers** to sustained widespread implementation of the top-ranked technology application within each representative country. Drivers and barriers considered were: cost and financing; laws and policies; social values, public opinion, and politics; infrastructure; privacy concerns; resource use and environmental health; research and development investment; education and literacy; population and demographics; governance and political stability. Combining the capacity to acquire technology applications with the drivers and barriers allowed us to evaluate the capacity of each representative country to implement the top-ranked technology applications, and on this basis the foresight experts were able to draw conclusions concerning cross-country variations.

Regional Disparities

Where people live will have a big impact on how new technology applications affect their personal health and standard of living and the environment. The 29 representative countries fall into four levels of science and technology capacity:

- **Scientifically Advanced** countries - Australia, Canada and Germany representing Western Europe and Israel, Japan, South Korea and the U.S. - will benefit from most technology advances, regardless of sophistication. These countries will be poised to implement, as they choose - e.g., targeted drug therapies, improved and less invasive diagnostics and surgery, engineered tissues, ubiquitous information access, advanced security methods, environmentally-friendly manufacturing, ubiquitous tracking devices, and pervasive sensor networks.
- **Scientifically Proficient** countries - China, India and Poland representing Eastern Europe, and Russia - will benefit from many, but not all, of the most sophisticated technology advances. These countries will likely see vastly improved medical diagnostics, drug therapies, and surgical procedures, advanced security techniques, as well as all of the improvements described below for the scientifically developing countries.
- **Scientifically Developing** countries - Brazil, Chile, Colombia, Indonesia, Mexico, Turkey, and South Africa - will be poised to take advantage of modestly sophisticated technology advances. These countries will have access to more efficient and environmentally friendly transportation technologies and manufacturing, as well as improved medical diagnostics and all of the improvements described below for the scientifically lagging countries.
- **Scientifically Lagging** countries - Cameroon, Chad, Dominican Republic, Egypt, Fiji, Georgia, Iran, Jordan, Kenya, Nepal, and Pakistan - will need to make concerted efforts to eliminate barriers to and support simple technology advances. The principal drivers for advanced technology implementation in these countries will be human development needs, effective management of resources, and prevention of pollution and environmental damage. The most challenging barriers will include honest and effective governance, political stability, and matching of the available technology applications to the social and cultural conditions and local needs such as remote power and communications, clean water, and food and shelter.

The 16 Top Ranking Applications Identified

The following were the top-ranked 2020 technology applications:

- **Cheap solar energy:** Solar energy systems inexpensive enough to be widely available to developing and undeveloped countries as well as to economically disadvantaged populations that are not on existing power grids.
- **Rural wireless communications:** Widely available telephone and Internet connectivity without a wired network infrastructure.
- **Communication devices for ubiquitous information access:** Communication and storage devices - both wired and wireless - that provide agile access to information

sources anywhere, anytime. Operating seamlessly across communication and data storage protocols, these devices will have growing capabilities to store not only text but also meta-text with layered contextual information, images, voice, music, video, and movies.
- **Genetically modified (GM) crops:** Genetically engineered foods with improved nutritional value - e.g., through added vitamins and micronutrients, increased production - e.g., by tailoring crops to local conditions, and reduced pesticide use - e.g., by increasing resistance to pests.
- **Rapid bioassays:** Simple, multiple tests that can be performed quickly and simultaneously to verify the presence or absence of specific biological substances.
- **Filters and catalysts:** Techniques and devices to effectively and reliably filter, purify, and decontaminate water locally using unskilled labor.
- **Targeted drug delivery:** Drug therapies that preferentially attack specific tumors or pathogens without harming healthy tissues and cells.
- **Cheap autonomous housing:** Self-sufficient and affordable housing that provides shelter adaptable to local conditions as well as energy for heating, cooling, and cooking.
- **Green manufacturing:** Redesigned manufacturing processes that either eliminate or greatly reduce waste streams and the need to use toxic materials.
- **Ubiquitous radio frequency identification (RFID) tagging of commercial products and individuals:** Widespread use of RFID tags to track retail products from manufacture through sale and beyond, as well as track individuals and their movements.
- **Hybrid vehicles:** Automobiles available to the mass market with power systems that combine internal combustion and other power sources.
- **Pervasive sensors:** Presence of sensors in most public areas and networks of sensor data to accomplish widespread real-time surveillance.
- **Tissue engineering:** The design and engineering of living tissue for implantation and replacement.
- **Improved diagnostic and surgical methods:** Technologies that improve the precision of diagnoses and greatly increase the accuracy and efficacy of surgical procedures while reducing invasiveness and recovery time.
- **Wearable computers:** Computational devices embedded in clothing or other wearable items such as handbags, purses, or jewelry.
- **Quantum cryptography:** Quantum mechanical methods that encode information for secure transfer.

Lagging Countries Need Stable Institutions and Social Equity First

For scientifically lagging and developing countries, implementing technology applications to address problems and issues will not be primarily about technology, or even science and technology (S&T) capacity. The greater challenge they will face is the lack of institutional, human, and physical capacity, including effective governance. Development results from improvements in economic growth, social equity, health and the environment, public safety and security, and good governance and stability. Those countries with the best performance in these indicators of development will most likely have the greatest institutional, human, and physical capacity to implement technology applications. Less-developed countries that hope to benefit from technology applications will have to improve their performance in these development areas to build the requisite institutional, human, and physical capacity.

However, several of the technology applications listed in the previous section require little S&T capacity - e.g., cheap solar energy can provide power for water pumping and irrigation, as well as lighting and village electricity. Together with rural wireless communication, it can enable rural education, as well as cottage industries for rural economic development. The addition of filters and catalysts to provide clean water and improved rural hygiene could enable vast improvements in health and human development. Genetically modified crops have the potential to address severe local and regional problems stemming from malnutrition.

Trajectories of the Global Technology Revolution

As the global technology revolution proceeds over the next 15 years, it will follow a trajectory with certain defining characteristics.

Accelerated Technology Development Will Continue: The authors of the forward looking study see no indication that the rapid pace of technology development will slow in the next decade and a half. Nor will the trends toward multidisciplinarity and the increasingly integrated nature of technology applications reverse. Indeed, most of the top 16 technology applications for 2020 draw from at least three of the areas addressed in this study - biotechnology, nanotechnology, materials technology, and information technology - and many involve all four. Underlying these trends are global communications - Internet connectivity, scientific conferences, and publications - and instrumentation advances - the development and cross-fertilization of ever more sensitive and selective instrumentation.

Different Countries Will Benefit in Considerably Different Ways: Over the next 15 years, certain countries will possess vastly different S&T capacities. They will vary considerably as well in the institutional, human, and physical capacity required to develop drivers for implementing technology applications and overcome barriers. Furthermore, different countries have different needs and uses for technology applications.

Consequently, the global technology revolution will play out quite differently among nations.

Scientifically Advanced Countries will Gain the Most: The scientifically advanced countries of North America, Western Europe, Asia, and Australia are likely to gain the most as exemplified by their capacity to acquire and implement all of the top 16 example technology applications. For whatever problems and issues that rank high on their national agendas, they will be able to put into practice a wide range of applications to help address them.

Emerging Economies to Use Technologies for Continued Growth: If they can address multiple barriers to implementation, emerging economies such as China and India in Asia and Brazil and Chile in South America will be able to use technology applications to support continued economic growth and human development for their populations. China and India as emerging technological powers will have the best opportunity to approach the ability of the scientifically advanced countries to use applications to achieve national goals.

The scientifically proficient countries of Eastern Europe, as represented by Poland, appear to be poised next in line behind China and India. In contrast, it looks likely that Russia's capacity to implement technology applications will continue to deteriorate, with the most advanced of the scientifically developing countries - represented by Brazil, Chile, Mexico, and Turkey - potentially overtaking her.

Lagging Countries Endangered of Falling Further Behind: The scientifically lagging countries around the world will face the most severe problems - disease, lack of clean water and sanitation, and environmental degradation. They will also likely lack the resources to address these problems. Consequently, they stand to gain the most from implementing the 2020 technology applications. However, to do so, these nations will need to make substantial inroads in building institutional, physical and human capacity. The efforts and sponsorship of international aid agencies and countries may assist in these efforts, but the countries themselves will have to improve governance and achieve greater stability before they will be able to benefit from available S&T innovations.

Actions Required for Maintaining a High Level of S&T Capacity: The accelerating pace of technology development and the growing capacity of emerging economies to acquire and implement technology applications will make economic security a moving target even for the most advanced nations. If countries are to stay ahead in their capacity to implement applications, they will need to make continuing efforts to assure that laws, public opinion, investment in R&D, and education and literacy are drivers for- and not barriers to- technology implementation. In addition, they will have to build and maintain whatever infrastructure is needed to implement those applications that will give them a competitive advantage.

Some Technology Applications Will Spark Heated Public Debate: Several of the top-ranked technology applications will raise significant public policy issues that will trigger strong, and sometimes conflicting, reactions and opinions between countries, regions, and ethnic, religious, cultural, and other interest groups. Many of the most controversial applications will involve biotechnology - GM crops, for example. Others, such as pervasive sensors and certain uses of RFID implants to track and identify people, will potentially have provocative implications for personal privacy and freedom. Yet any controversy that flares up will probably not be the same around the world. A technology application that could raise extremely divisive questions in one country may cause no stir at all in another due to different social values.

Consideration Can Head-off Problems and Maximize Benefits: Public policy issues will need to be resolved before a country will be able to realize the full benefits of a technology application. Not all technology may be good or appropriate in every circumstance and just because a country can do a thing does not necessarily mean that it should. Ethical, safety, and public concerns will require careful analysis and consideration. Public policy issues will need to be debated in an environment that seeks to resolve conflicts. Such public debates, in addition to being based on sound data, will need to be inclusive and sensitive to the range of traditions, values, and cultures within a society. In some cases, issues will remain after the debate, slowing or even stopping technology implementation. Sometimes the reasons will be clearly good - e.g., when safety concerns cannot be adequately addressed - and sometimes the result will simply reflect collective decision-making determining what a particular society wants and does not want.

Sources and References

The Global Technology Revolution 2020, Executive Summary: Bio/Nano/Materials/Information Trends, Drivers, Barriers and Social Implications, MG-475-NIC, RAND Corporation, (2006). The Global Technology Revolution 2020, In-Depth Analyses: Bio/Nano/Materials/Information Trends, Drivers, Barriers and Social Implications, TR-303-NIC, RAND Corporation, (2006) and The Global Technology Revolution: Bio/Nano/Materials Trends and Their Synergies with Information Technology by 2015, MR-1307-NIC, RAND Corporation 2001. All are available from www.rand.org/pubs.