Trends and Future Values in Technology

This article identifies five technology product areas, or areas for applied scientific research, which have the most potential for innovation and expansion within Kentucky over the next 5 to 15 years. These areas are: telecommunications, life science technology, biotechnology, material design, and environmental remediation.

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From a global perspective the single most critical factor in the process of evaluating and forecasting the future of science and technology is compression of the time for discovery, creation, and commercialization of innovative technologies. Time has always been a critical element in the evolution of technology and the way new ideas are fashioned into applied science. But today, and into the future, critical successes will hinge not only on the timing of an event but also on the length of the time frame within which that event occurs. Not only will an idea have to occur at the time when it is most useful, it will occupy an increasingly shorter period of ascendancy before being supplanted by newer and more advanced ideas. Consequently, forecasting a future 5 to 15 years from now is like aiming at a moving target that changes direction and speed at will. At best, the forecaster will be right for only a small fraction of time.

Nevertheless, the microprocessor is almost certain to be increasingly important, and the rate of scientific and technical discovery is likely to accelerate. Three new broad areas of development will, in turn, affect every part of the evolution of science and technology. Firstly, the size of every working device will shrink. As machines continue to shrink at increasing rates, we will be able to move more information, more quickly, across wider distances. Secondly, this nano-technology will spawn a biogenetic revolution that will significantly affect the way in which humans exist by more fully integrating living organisms with non-living support devices. Thirdly, we will develop a highly sophisticated “artificial intelligence” that can be used in combination with human intelligence to escalate the development of the previous two processes. I point these concepts out not as an attempt to scare anyone with visions of a robotic future nor to put a “wet blanket” on the potential for excellence, but rather to alert all of us to the potential of this magnificent adventure in self discovery. To succeed we must constantly evaluate where we are in the process and anticipate high achievement rather than simply react to a realization that science and technology have changed.

In addition to global prospects, the process of technological innovation hinges on the presence of pioneers—firms and individuals—and a supportive local infrastructure. It is a two-way street. While innovative technology tends to issue from individual creators or champions within small economic units, the overall infrastructure established by government encourages or discourages innovation. But nothing is certain. All too often, pioneering companies find a comfortable niche and lose their pioneering spirit. What’s more, the risk pioneers take does not always pay off, as the work of seeking out and developing new technologies is costly and often subject to regulatory requirements designed to ensure product safety and efficacy. Moreover, products can be appropriated in the marketplace by firms that have invested little time and effort. As a consequence, individuals and firms can only do so much. Likewise, infrastructure can only do so much to facilitate success. Ultimately, we are able to achieve successful pockets of advanced technology when the individual or the enterprise risks becoming a technology pioneer and encounters a supportive infrastructure. Unfortunately, there is no precise formula that will ensure the successful advancement of technology. Therefore, any prediction will remain hostage to the interaction of the individual and the facilitating infrastructure.

In spite of the difficulty of creating the "right" infrastructure, I propose a series of specific technologies that are, at the very least, worthy of review and promotion at the state or regional level. I have concentrated on technologies for which global markets appear likely and a supporting infrastructure already exists in Kentucky. It is my belief, however, that all institutions of higher education or individuals with a pioneering spirit should make earnest attempts to participate in the research, development, and implementation levels of these technology areas. Further, the Commonwealth would do well to concentrate infrastructure-building efforts in these areas. Ultimately, scientific research within Kentucky's institutions of higher learning should become more attuned to the areas and to the potential for commercial application that they hold, an area that needs more emphasis if Kentucky is to become competitive in new technologies.

Increasingly, the federal government's approach to the discovery process is becoming limited to providing a framework, while leaving discovery and development to industrial and academic sectors at the state and local levels. The largest applied research funding source within the federal government, the Department of Defense, has been reducing its research and development budget and retargeting its dwindling resources to support dual use technologies, those with civilian as well as military applications. Given this situation, more of the research burden will continue to be shifted to the business and academic communities of states. Universities will be hard pressed to provide both basic and applied research capabilities without more active involvement from the business community and state government.

In January 1996, the National Science Board released a study of Science and Engineering Indicators, which examines all aspects of the research and development process from academic and industrial perspectives.[1] The United States, it concludes, is a world leader in science and technology, but that leadership has narrowed in relation to countries that have major commitments and capabilities and have increased their resources over the past two decades.[2] This dimension of global competition is significant for Kentucky because it opens new markets and new development opportunities for technologies derived from the rural, agricultural and extractive industries that have been the mainstays of the Kentucky economy for many years. Kentucky not only shares geographic and industrial similarities with many technology-developing countries, but infrastructure similarities as well. Many of the new technological competitors on the global scene have few major industrial centers and a limited breadth of technological expertise. Most global competitors will be emerging from traditional industrial technologies to compete in *limited* advanced technology markets that can be supported by existing infrastructure and economic resources. The implication is, of course, that Kentucky should identify a set of technological priorities based on its existing capabilities, its historical experience and expertise, its realistic economic and academic resources, and its desire to become a technological pioneer.

Future Technologies

I have selected five areas for technology products or applied scientific research which I believe will be important to Kentucky during the next 5 to 15 years. The technologies I have selected are all included in the U.S. Bureau of Census classification system, 10 Advanced Technology Product Areas. Technologies included on this list have historically led to leading-edge or pioneering products. These product areas are derived from the National Critical Technologies list of seven areas considered to be critical to develop and further long-term national

[1] National Science Board. (1995).*Science & engineering indicators–1996*. (NSB 96-21). Washington, DC: U.S. Govenment Printing Office.

[2] National Science Board, p xvii.

security or economic prosperity.[3] This list of seven critical technologies is closely monitored both in terms of imports and exports and in terms of academic research and development. The seven technology areas pertain mostly to scientific research, hence are useful for international benchmarking of intellectual activity.

The 10 Advanced Technology Product Areas are application-based derivatives of the critical technologies list. As such, they are oriented toward the commerce of innovation. Patenting activity has long been used as a marker of the direction of innovative development and scientific thinking. Each of the advanced technology product areas has experienced and continues to experience high levels of patent activity both in the United States and abroad, further confirming the categorization of these technologies as important to the global economy and the process of innovation. It is also important to recognize that these technology areas each represent very broad applied capabilities and innovative possibilities. The 10 advanced technology product areas are:[4]

- *Biotechnology*. The medical and industrial application of advanced genetic research to the creation of new drugs, hormones, and other therapeutic items for both agricultural and human uses.
- *Life Science Technologies*. Application of scientific advances (other than biological) to medical science. For example, medical technology advances such as nuclear resonance imaging, echo cardiography and novel chemistry, coupled with new production techniques for the manufacture of drugs, have led to new products that allow for control or eradication of disease.
- *Opto-electronics*. Development of electronic products and components that involve emission or detection of light, including optical scanners, optical disc players, solar cells, photosensitive semiconductors, and laser printers.
- *Computers and telecommunications.* Development of products that process increasing volumes of information in shorter periods of time, including facsimile machines, telephonic switching apparatus, radar apparatus, communications satellites, central processing units, computers, and peripheral units such as disk drives, control units, modems and computer software.
- *Electronics*. Development of electronic components (except for opto-electronic components), including integrated circuits, multi-layer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that result in improved performance and capacity and, in many cases, reduced size.
- *Computer-integrated manufacturing.* Development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles that allow for greater flexibility in the manufacturing process and reduce human intervention.
- *Materials Design*. Development of materials, including semiconductor materials, optical fiber cable and video discs, that enhance application of other advanced technologies.
- *Aerospace*. Development of technologies, such as most new military and civil helicopters, airplanes and spacecraft (with the exception of communication satellites), turbojet aircraft engines, flight simulators, and automatic pilots.
- *Weapons*. Development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers and some firearms.

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[3] National Critical Technologies Review Group. (1995, March). *National critical technologies report*. Washington, DC: Government Printing Office.

[4] National Science Board, 6.

- *Nuclear Technology.* Development of nuclear power production apparatus, including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life science rather than this category).

Selecting those technology areas and sub-areas with particular relevance to Kentucky is a risky proposition based on personal opinion, knowledge and, in some cases, almost entirely on gut-feeling. In addition to popular readings and the Census Bureau's analyses of trends in technological development, I have relied highly on the theory that a single event can have a significant impact on the innovation process. This, in effect, creates a filter by which technologies may be singled out without the interference of other market factors. The filter which I have used to select the emphasized technologies is based on my perception of the existing or developmentally possible science, technology and industrial resources of Kentucky and on the academic excellence or potential excellence of Kentucky educational resources. As I have indicated, it is probably not possible for a totally accurate picture of future technology to be developed at least on a narrow geographic level. An exhaustive study would require too much time, money and too many assumptions. In addition, it would be out-of-date before it could be completed. My suggestions of specific technologies are therefore merely suggestions of *potential.*

One major area of concern is public perception of the role of scientific discoveries and the new technologies within the economic and educational framework of Kentucky. Approximately 40 percent of Americans surveyed express a high level of interest in science discoveries and the use of new technologies. Individuals with more years of formal schooling and more courses in science and mathematics express significantly higher interest, demonstrating the persistent effect of science and mathematics education throughout the adult years.[5] Kentucky's relatively low position in terms of literacy and other educational measures is disturbing to any prediction of technological advancement. A citizenry that is uninterested in science and technology because it has an inadequate education is unlikely to support an infrastructure to develop technology. Further, such citizens are unlikely to become employees of technology-based businesses, given their lack of educational achievement.

Unless rapid change is effected, this problem of today will translate into failure in the future. Significant steps are being taken to increase the technology and scientific sophistication of children in Kentucky's school systems today, in the hope of producing a workforce and a population that will benefit from tomorrow's technology. The struggle will be within the legislating bodies of Kentucky, which will be challenged to act on faith that the selective development of infrastructure improvements and processes for seeding technologies with growth potential in Kentucky will help cultivate islands of opportunity and growth that will ultimately result in the economic betterment of the Commonwealth.

Infrastructure and potential are only two of the three significant factors in successful technological innovation. The makeup of individuals and companies in the state, the ability to attract individuals and companies, and the ability to instill in this group the desire to be a part of the advance of technology is the third, and many would argue, most important factor. Having led our technology horses to the water, we now have the task of making that water (future technologies) so attractive that they cannot resist the temptation to drink. All of the technologies I am about to suggest are doable, within the constraints of funds, education and other resources available to Kentucky, but the will to excel is the difference between success and failure in any of these areas.

The five technology areas which I believe have the most potential for innovation and expansion in Kentucky are:

Telecommunications. Specifically, we should focus on the technologies of networking and infrastructure development. Information interchange is taking on increasingly diverse forms.

[5] National Science Board.

Kentucky is already a leader in statewide communications systems. It now needs to expand communications capabilities for more broadband information transfer to all segments of its population. In terms of satellite communications, Kentucky has an experience base in distance learning and the application of sideband information transmission. Opportunities to develop these resources include the presentation of public education in a uniformly excellent manner to all students within the state. It is important to be willing to promote the virtual reality classroom and the teleported teacher. This process can become a partnership of public and private organizations that will continue to blur (for the better) the distinction between the schoolroom and on-the-job industrial training. The outcome is likely to be much-desired educational improvement.

Likewise, networks for the evolution of commerce as cooperative and joint ventures between many small and individually capable organizations should be an expressed goal. To accomplish it, Kentucky research institutions should be considering projects that will reduce the size of transmission and control equipment, increase the speed of data transmission, and more fully integrate the human-machine potential of our existing communications networks. Futuristic factories will require machine-to-machine interfaces at an increasingly more complex level. Tremendous amounts of information will have to be transported from designing and prototyping machines, to the actual manufacturing process, most of which will be possible without human intervention but responsive to human control.

For example, it will soon be possible for a machine design change to be made as a result of the detection of a part failure in the field. Failure information will be fed to a design machine and from there to a manufacturing machine which will create the modified part. Any or all of these machines may be located remotely from each other. This entire process will take place without direct human intervention other than to monitor and acknowledge the process. Electronic Data Interchange (EDI) is not just the wave of the future. It is a here-and-now technology that is ideally suited to innovative Kentucky businesses. By exploring and implementing EDI, many small and otherwise uncompetitive Kentucky businesses can combine to create a virtual manufacturing entity capable of large-scale contracts and high-quality production.

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All forms of public communications media are moving toward integrated, electronically based systems. The imminent deployment of interactive cable television and the national development of the “information superhighway” should stimulate cooperation between Kentucky educational and economic institutions. This will facilitate full information access for all individuals and businesses in the Commonwealth. The phenomenal growth of the Internet for commercial purposes will offer Kentucky businesses many great opportunities to capitalize on their individual expertise as it applies to the international marketplace. Global commerce is now not so much a dream but an eminently doable process whereby Kentucky companies can forge links with other providers and consumers to deliver Kentucky-born expertise, goods, and services to a waiting world.

The manufacture of communications tools by Kentucky companies will be limited to component assembly and packaging in the short term and may be stifled over the long term unless specific centers of academic and research excellence can be developed to support the innovation to commercialization process. At present, Kentucky industry does not have the potential for large-scale growth in the product development area of telecommunications. Historically, Kentucky’s electronics industry has followed blueprints or designs of others (mostly from outside the state). Evolution of the internal capacity to expand this sector will ultimately be based on the capacity of academic and research institutions in the state.

In contrast, significant potential exists for the manufacture of sub-components. The manufacture of switches, connectors, and transmission media that will be the backbone of tomorrow's telecommunications industry is based on technology that is well within the current capabilities of Kentucky companies. The choice can be made to continue along the path of a job shop environment or to pursue the more ambitious process of facilitating the commercialization of innovations produced by Kentucky academic and research institutions. Development of the latter capacity to its highest potential is within the ability of academic institutions and telecommunications-based companies in the state and a critical step if this industry segment is to become a viable part of the 21st century economy.

Life Science Technology. Nano-technology medical devices, which can be used as human replacement parts or as diagnostic and surgical repair robots, are likely to be a significant technology force in the very near future. Coexistent with the development of these devices will be the technical implantation and remote control skills needed to implement their deployment. An example of this type of technology would be microscopic devices that "cruise the bloodstream searching for fat deposits and infectious organisms" they destroy.[6] Kentucky has several centers of medical excellence and is strategically located within consultation/collaboration distance of several more. Kentucky has demonstrated research and development capabilities in the micro-machine arena and in microsurgery. By encouraging networking and cooperation among the medical research community and the health sciences applications arena, new products in nano-technology diagnostic and surgical applications could be developed using existing resources. Such products would have worldwide marketability and enormous economic potential for Kentucky companies.

Also included in this category are pharmaceutical products that can be delivered to the patient through a variety of media. *Business Week* reported that the *drug distribution* field saw earnings jump 459 percent from 1991 to 1992.[7] With an already firm base in pharmaceutical research and potential for large-scale human and animal testing, this technology should be encouraged and supported by local and statewide initiatives. Existing infrastructures in pharmacology research need to be maintained and strengthened and additional encouragement given to pharmaceutical manufacturing companies to form or relocate in Kentucky to facilitate growth in this sector. In addition, the drug delivery research initiatives already underway need to be encouraged, as they will become a significant new method of health care delivery.

Biotechnology. Two areas of new development with potential involvement by Kentucky academic and industrial institutions are Recombinant DNA techniques and Monoclonal antibodies used in diagnostic testing. Recombinant DNA techniques (genetic engineering or "gene splicing") have spawned the most profitable success to date and are likely to continue to produce breakthrough drugs in the future.[8] Particularly in the areas of agricultural feed development and crop immunization, Kentucky has a significant investment in scientific and technical expertise. Capitalizing on engineered feeds for livestock, the biotechnology industry in Kentucky has the potential to profoundly impact the market over the next 20 years. Given the worldwide need for economies in food production, Kentucky companies must recognize their potential to make a major contribution to innovative, applied agricultural science.

Monoclonal antibodies and DNA probes are biotechnology products used in medical diagnostic testing. Examples include a technique for imaging fibrin clots, an early indicator of heart disease. More specially engineered substances that make entire new realms of testing possible will appear. As physician liability for malpractice increases, the demand for more ac-

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[6] Petersen, J.L. (1993). *The road to 2012: Looking towards the next two decades.* Arlington, VA: Arlington Institute, p. 66.
[7] Dickinson, M. (1992). *Who invented what, 1992.* New Haven, CT: Opus Publications, p. 46.
[8] Dickinson, 24.

curate tests and more testing continues to grow.[9] Far and away the largest category of biotechnology patents issued by the U.S. Patent and Trademark Office in 1992 was drug, bio-affecting and body treating compositions. The potential for development and the process of administration of new pharmaceuticals in conjunction with this biotechnological activity is clearly one of the best opportunities for growth in Kentucky's technological future.

Materials Design. Advanced materials is an extremely broad and active area of technology development. Development in this area has arisen from increased awareness of the need to conserve existing natural resources and cope more effectively with a changing or deteriorating natural environment. The products being created respond to needs for lighter, more corrosion resistant products that will be stronger in new environments. As we push the present limits of micro-technology toward the concepts of nano-technology, we will be increasingly concerned with the structure and composition of the materials used to house products.

While we anticipate tiny, self-contained computing/communicating devices that will be carried in our shirt pockets, those devices cannot become reality unless the package in which they are housed can be made lighter, smaller, and stronger than present materials permit. Of the three major categories of composite materials—ceramic matrix composites, polymer matrix composites, and metal matrix composites—Kentucky is already involved in the first category and various industries within the Commonwealth are researching or developing applications for the second.

Kentucky industry is capable of developing critical technical know-how, and the state's research community is beginning to demonstrate more intense interest in materials design.

One of the major change agents in the field of advanced materials is the burgeoning automotive manufacturing sector, which includes major assembly plants and an extensive parts supply sector located throughout Kentucky. As transportation manufacturers seek to reduce weight, improve corrosion resistance and increase the strength of their final product, they will exert an inexorable force on their suppliers to seek new fabricating materials. Potentially, the ceramic and polymer matrix technology sectors could become a significant economic factor in Kentucky manufacturing, as well as in the scientific economy.

While much of our technology is now imported from other states or other countries and simply applied to existing industry, it is well known that Kentucky industry is capable of developing critical technical know-how, and the state's research community is beginning to demonstrate more intense interest in this emerging field. New wood-forming technologies, for example, are being used to create valuable dimensional lumber from previously under-utilized Kentucky hardwoods. This represents a significant advancement in Kentucky's efforts to develop new materials that capitalize on natural resources in this state. This also represents a noteworthy advance in the technological orientation of the wood processing industry that could lead to important advances in natural materials products that meet the same needs as manmade materials.

Environmental Remediation. Although not a technology product area noted by the Census Bureau, no sector of emerging technologies holds as much promise for Kentucky as does the arena of environmental remediation. Each of the Advanced Technology Product Areas cites pollution prevention and environmental remediation as an essential part of the manufacturing process. Environmental protection can be expected to be a required part of any new product development in the 21st century. In addition, worldwide industry has left a legacy of earlier

[9] Dickinson, 25.

industrial pollution that begs for remediation. Both the state and companies within it have done much to exploit the abundant natural resources with which Kentucky was endowed. Unfortunately, there are many instances in which exploitation turned into abuse and neglect. In recent years, state firms and state government have acted responsibly to recover and recycle resources and explored many opportunities for remediation. Four of the top 10 U.S. companies that filed for environmental remediation patents in 1992 had operational facilities in Kentucky.

The United States generates 180 million tons of municipal solid waste annually and landfills more than 130 million tons of this material. By the year 2000, more than 54 million tons of waste products will be without a suitable dump site. Waste paper and wood wastes are the single largest component of municipal waste—nearly half by weight. Bio-conversion of wood fibers will allow new uses for waste wood, mostly in building materials."[10] Rather than becoming a dumping ground for industrial and biological waste from other states, Kentucky can become a remediation and reprocessing center with economic potential coming from our positive location within the national transportation grid and our abundance of other raw feed stocks to add to the materials shipped in for recycling.

The potential technologies for development in Kentucky include sulfur dioxide emission control, oil waste water or acid mine drainage pollution remediation, and biodegradation of existing organic hazards. Unfortunately, this entire area is one in which the scientific and technical issues are more often than not victims of economic and political considerations. Funding for research activities that could lead to breakthrough advances in all areas of environmental remediation have been highly publicized but minimally financed. Kentucky has begun many initiatives and still has much to accomplish in this technological quarter, but the fact that we have begun and that we are aware of the need places Kentucky industry and technology infrastructure ahead of other states and most countries.

Conclusion

Time, change and rate of change will be the significant factors in shaping the future of Kentucky science and technology. The Information Revolution will provide the paradigm shift to stimulate this change. The infrastructure that will encourage and ultimately support the discovery, development and application of future Kentucky science and technology is now being put into place. It requires improvement, innovation and additional support from all sectors of the economy.

The obvious starting point is continuous improvement of the education system, particularly in the areas of mathematics and science. This needs to be followed by an emphasis on attracting and nurturing technology pioneers in Kentucky. Successful accomplishment of these first two steps will strengthen Kentucky science and technology industries and prepare them to become competitive factors in the global economy of the 21st century. The third part of this forecast presents those specific technologies which I believe hold the greatest potential for development within the economic framework of the Commonwealth. The major and projected strengths of Kentucky scientific expertise and developable technologies lie in the fields of telecommunications, medical products, biotechnology, advanced materials, and environmental remediation. While it is impossible to accurately predict specific success or failure in any one of these cited fields and equally impossible to rule out the advent of an entirely new area of advancement unrelated to the cited fields, it would appear likely to this observer that a concentration of economic and human effort in the fields noted offer an effective use of the limited developmental resources available over the next decade.

[10] Dickinson, 39-40.