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The Next Innovation Revolution

Laying the Groundwork for the United States

Nations seem most open to economic innovation when they feel threatened. In the late 1970s the United States experienced this: slipping competitive position compared to Japan convinced policy-makers that strategic adjustments to compete were necessary. In 1979, President Carter's Domestic Policy Review on Industrial Innovation (DPR) provided a road map for optimizing U.S. society for innovation and for responding to Japan's industrial policy. While the DPR benefited from earlier studies, it proved to be the right study at the right time.[1] It championed cooperation among industry, universities, and the government, then a fresh idea, and promoted cooperative research among U.S. companies. And it systematically examined federal policies to see what changes in law and administration policy were needed to permit American researchers from all sectors to work together. The resulting changes were neither entirely new ideas nor immediate, and innovation policy had different emphases in each successive presidential administration. But, looking back, it is clear that the DPR proposals led to revolutionary changes, both within companies and in the ways they relate to other companies and universities —and thus provided the nation with a significant competitive advantage.

But that advantage was temporary. Today, twenty-five years later, many in the United States again feel threatened by international competition. The edge the U.S. achieved through innovation policy changes in the 1980s and early 1990s has largely disappeared. Other nations have adopted, and in some cases improved upon, most of these policies. The U.S. is now experiencing record trade deficits and budget deficits and international competition is fierce. Once again, key American companies are on the ropes.

Fortunately, the advent of the Internet and other key software developments provide a new set of potential revolutionary changes in the way people and organizations work together. Far-reaching opportunities are available to improve the

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ways government and society are organized to relate to business and for companies to improve their internal and external relations. This will require legislative and administrative revisions and behavioral changes by all involved. While the academic community and elements of the business community seem to be coalescing around a proposed set of next steps, U.S. political leaders are less unified than in the 1970s. The jury is still out on whether the U.S. can develop a sufficiently broad and ambitious common vision, but the intense pressures on industry may move other parts of society toward their vision. How will the U.S. respond? Will it, or other nations, achieve first-mover advantages in this next round of restructuring for innovation? The answers to these questions will affect the nation's future well-being and competitiveness with other nations in ways that we are only beginning to understand.

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THE 1979 INNOVATION REVIEW

The United States was caught flat-footed in 1979 when Japan emerged as a manufacturing power and u.s. domestic cost of doing business was rising rapidly. The U.S. moved rapidly, from industrial dominance in autos, steel, and computers in the 1960s and early 1970s, to such weakness in the late 1970s and early 1980s that some key companies needed government intervention to survive. The United States had not kept up with the times. The U.S. economy was organized around major vertically-integrated companies. They did their own research. They depended on volume and large inventories to deliver products on time. They dictated to suppliers. Many of the federal government's responses to these challenges were short-term financial fixes: the Chrysler loan guarantee, support of chipmakers through the SEMATECH consortium, and the Synthetic Fuels Corporation that helped commercialize alternatives to crude oil. In time, a much more profound and lasting impact came from a series of low- or no-cost policy changes to the social capital of the U.S.: the set of policies that determines how efficiently the U.S. can conduct business. Many of these changes were initially proposed during the Carter Administration; most came to fruition in a modified form during the Reagan years.

On October 31, 1979, President Carter unveiled the President's Industrial Innovation Initiatives, the result of an 18-month Domestic Policy Review (DPR) carried out under the leadership of Jordan Baruch, then Assistant Secretary of Commerce for Science and Technology, and involving approximately 500 private-sector participants and 250 representatives from 28 federal agencies. The initiatives reflected a strong belief in the free enterprise system and an equally strong belief in the federal government's responsibility to nurture an environment in which industry, universities, and government can function smoothly together. Baruch and his colleagues sifted through many task force reports to come up with nine priority areas, aimed largely at bringing together the strengths of industry, universities and government, especially in research. The president endorsed their work. The initiatives package contained nine key proposals:

Enhance transfer of technological information to industry by expanding the domestic and international capabilities of the National Technical Information Service (NTIS).

Increase technical knowledge by creating generic technology centers at universities, funded jointly by the National Science Foundation (NSF) and industry, through federal investment in developing the technologies that industry needs to meet regulatory requirements, and by improving university-industry cooperation in research and development.

Improve the patent system. Develop a uniform federal patent policy, establish a single court for patent appeals, and improve public access to information held by the U.S. patent office, among other initiatives.

Clarify antitrust policy. Make it clear that collaboration on basic research is not an antitrust violation and dispel the misconception that antitrust policy inhibits innovation.

Foster the development of smaller innovative firms. Increase NSF's nascent Small Business Innovation Research (SBIR) program and explore the possibility of expanding it to other agencies. Have the Department of Commerce increase direct equity investment in startups by promoting state or regional corporations for industrial development. Make more venture capital available, and change agency policies to increase the small business share of their R&D contracts.

Open federal procurement to innovations. Substitute performance specifications for design specifications, focus on life-cycle costs rather than initial purchase price, and pay special attention to small businesses.

Improve the regulatory system, including innovation waivers of regulatory requirements.

Facilitate labor/management adjustment to innovation, including a national labor/technology forecasting system that would allow time to train and retrain workers.

Maintain a supportive climate for innovation. Improve engineering and business school curricula in technology management and innovation. Have the executive branch monitor innovation activities, including efforts to remove legislative and administrative barriers to innovation.[2]

Thus a shift began, from companies acting as fiefdoms to sectors of society working together. Breaking the initiatives down by sector, the DPR proposed specific initiatives to strengthen the innovation capabilities of all three sectors.

- Businesses would benefit from antitrust and labor/management reform, SBIR, the Corporations for Industrial Development, and patent reform.
- Universities would benefit from patent reform, the development of innovation

curricula, and generic technology centers.

- Government would benefit as NTIS strengthened information policy, as it built up control over patents, and through reformed procurement and regulatory practices.

Legislative Response: The Carter Years

Work began almost immediately on these provisions to strengthen each sector's abilities to contribute to innovation, and two important bills were quickly enacted. In October 1980, President Carter signed the Stevenson-Wydler Technology Innovation Act of 1980 (Stevenson-Wydler Act). It authorized the Department of Commerce and the NSF to create Centers for Industrial Technology at universities to promote cooperative research with industry, assist small businesses and start-ups, and develop curricula. It also created the Center for Utilization of Federal Technology at NTIS, created technology transfer offices in the federal laboratories, and established a National Technology Medal. Fifteen days later, Carter lost his re-election bid to Ronald Reagan. In December, during a lame duck session, Congress passed, and Carter signed, the Bayh-Dole Act which began the process of establishing a uniform federal patent policy.

Legislative Response: Subsequent Years

While President Carter's Domestic Policy Review died with the start of the Reagan revolution, the Stevenson-Wydler and Bayh-Dole Acts remained on the books. The underlying problems that the DPR addressed did not go away. Dr. Baruch's successor was Dr. Bruce Merrifield, Assistant Secretary for Productivity, Technology and Innovation in the Reagan Administration. He and his staff spent the next several years pushing their own versions of innovation reform. Although Bayh, Stevenson, Wydler, and most of their staffers left Congress at the end of 1980, some of their colleagues who had helped write these laws stayed there or moved to the Reagan Administration and continued the work. While the Reagan Administration kept new domestic spending programs to a minimum for the next six years, some in Congress were eager to work with the administration to address competitiveness issues through structural reforms and tax policy. Major policy changes that did not involve Federal appropriations sometimes passed with little or no opposition. In fact, during this period, innovation policies jointly developed by the Reagan Administration and the Congress at least partially addressed all of the DPR areas of concern, except for procurement and regulatory reform.

Key Reagan-Era Legislation Impacting Innovation

The version of the Bayh-Dole Act in place at the end of the Carter Administration was far from the uniform federal patent policy that the DPR had recommended. Opponents of the original Bayh-Dole Act strongly opposed the act as a giveaway of federal property—even though that property had little or no value while in federal hands. There was little incentive to commercialize federally-funded inventions and the government retained up to 20,000 of them, unlicensed. The act passed only after its sponsors made major concessions; one was limiting its applicability to small businesses and non-profit organizations. This situation changed with Reagan's Presidential Memorandum on Government Patent Policy and Executive Order 12591, which made the Bayh-Dole Act applicable to all businesses unless otherwise prohibited by law; later the 1984 Bayh Dole Amendments extended the act's provisions to federal laboratories and cleared up other problems.[3] Since then, the Bayh-Dole Act has been the dominant patent policy for federally-funded inventions. Most of the other patent changes recommended by the Carter DPR, including consolidating patent appeals in one federal court, were also made during the first Reagan term.

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The Bayh-Dole Act, as amended and implemented, ended a major barrier to private-sector use of federally-funded research; university-industry cooperation in research began to increase dramatically.[4] The huge increase in patenting opportunities also led to unanticipated, fundamental changes in the way universities operate and helped them become major economic players in their own right. Since the Bayh-Dole Act, universities have received billions of dollars in royalty payments from the licensing of federally-funded inventions and well over 1000 companies have started up based on federally-funded patents.

Activity related to the act is still increasing rapidly. For example, attendance at the annual meeting of the Association of University Technology Managers has risen from 50 the year the act was passed to over 5000 today, and legislation inspired by Bayh-Dole has been enacted in most industrialized countries. According to a 2002 article in the *Economist*, entitled Innovation's Golden Goose, the Bayh-Dole Act is "possibly the most inspired piece of legislation to be enacted in America over the past half-century," as it led to the creation of 2000 new companies, 260,000 new jobs, and a $40 billion annual increase to the U.S. economy.[5]

Before 1980, few universities had the capability to license inventions. Since the act passed, universities and government contractors routinely choose to retain rights to their inventions made under federal grants and contracts; their employee inventors generally share in any royalty streams from the licensing of the inventions. The act and its incentives have contributed to a fundamental change in the relationship between universities and industry, and cooperation is occurring in ways never dreamed of a quarter century ago. In engineering schools, medical schools, and many science departments, some professors have moved from consulting with industry to participating in startups and holding financial stakes in the companies they assist. Many universities have moved beyond technology licensing and now actively support startup companies sometimes headed by a professor or graduate inventor; they even take equity positions in these companies.

Technology-based companies also are increasingly locating personnel at or near research universities to take advantage of university expertise. As of March 2006, the Association of University Research Parks had 134 members in 44 states. The average park had 51 companies; altogether they had a total of 144,260 full-time employees and 23,506 students and interns working; 76 percent had current plans for expansion.[6]

Another key piece of legislation was the National Cooperative Research Act (NCRA) of 1984. In 1979 the DPR had stated that anti-trust laws are often mistakenly understood as preventing cooperative basic research, even when doing so would foster innovation without harming competition. Corporations were generally not interested in joint research because a couple of legal precedents indicated the potential for liability under federal antitrust law. This was also a time of great stress for the semiconductor industry; most U.S. semiconductor companies were young and not firmly established; for instance, Robert Noyce of Intel had participated in the 1978-9 DPR initiative as a small business representative. With large Japanese companies moving rapidly into the dynamic random access memory chip (D-RAM) business, the government agreed with the U.S. industry's conclusion that it needed a research consortium (SEMATECH) to survive. The effort to form SEMATECH was the driving force behind the NCRA.

NCRA reversed the burden of proof in joint research antitrust cases, whether basic or applied, and thus removed the incentive for private parties to bring joint research antitrust cases. In doing so, NCRA began a chain of events that may have had even a larger impact on how technology-based businesses operate than Bayh-Dole had on universities. Overnight, attorneys changed their advice and joint research became fashionable. Large companies that had virtually no industrial partners in 1984 had acquired thousands by the early 1990s. In turn, many small high-technology businesses started up, partnering with large businesses that could now legally be major consumers of their research and development results. The speed and diversity of research and development accelerated; no longer could any company, no matter how large, depend only on its home-grown technology. As central corporate research labs declined, university startups began the rapid growth that continues to the present.

The NCRA also led to a change in thinking about the very nature of antitrust. Just nine years later, the antitrust climate in the United States had changed so significantly that the act was expanded to include joint manufacturing when Toyota and General Motors decided to form a joint venture to make nearly identical automobiles on the same assembly line. Companies that a decade earlier were afraid to do basic research together now were making cars together. While clearly the NCRA did not cause all these changes single-handedly, it freed businesses first to do research together and then to manufacture together, thus speeding the rate of change. And now, international antitrust law is harmonizing and joint manufacturing occurs worldwide.

A third key piece of legislation was the National Technology Transfer Act of 1986. It was based on a systematic look at what it would take to increase the flow of commercial ideas from government laboratories to the private sector. Probably the most important innovation in this act was the Cooperative Research and Development Agreement (CRADA), which provided a legal means for laboratories and outside parties to work together without the formalities of a contract or cooperative agreement. Over the years a huge body of boiler-plate conditions had been added to the federal acquisition regulations and the defense acquisition regulations, creating a major impediment to executing relatively simple transactions. With a CRADA in place, some agencies could work out an agreement one week and begin collaborating the next.[7] Included in the same act were a set of Bayh-Dole-like provisions that permitted federal inventors to share in the profits from their inventions. Experience had taught us that the laboratory compensation system did not reward employees for putting in the extra effort required to ready their inventions for commercialization. Revenues from the licensing of federal laboratory inventions have increased several hundred fold since this provision went into effect.[8]

By the end of the Reagan years, even the functions of the Centers for Industrial Development, a part of the Stevenson-Wydler Act that the Reagan Administration had chosen not to establish, reappeared in other forms. The NSF funded Engineering Research Centers at universities to promote university research that would solve generic industry problems and to integrate industry needs more thoroughly in the agency's research and development agenda. The Omnibus Trade and Competitiveness Act of 1988 contained several innovation initiatives; one was the Manufacturing Extension Partnership (MEP), centers to help small- and medium-sized manufacturers to modernize.[9] This program was extended during the George H.W. Bush Administration and was implemented nationwide under President Clinton.

Policies that Increased Research Funding

In 1982, with the enactment of the Small Business Innovation Development Act, the SBIR program began to change, from an NSF experiment to the federal government's largest source of funding for small high technology businesses, fueling their rise. It implemented the DPR recommendations to enlarge the NSF's program and to consider expanding it to other federal agencies. What was in 1982 a $5 million NSF program now awards over $2 billion in grants per year in eleven agencies.

Initially, the program was quite controversial. Supporters had no hard data to back up their assertions that small businesses were the nation's primary source of innovation in the economy. At the time it was passed, the most recent statistics available showed that only 5.5 percent of scientists and engineers worked for small businesses; agencies complained that they were being forced to fund research that was below the quality of peer-reviewed research. Congressional critics could not see enough technologically-based small businesses to fund, especially in areas like biomedical research that were traditionally the domain of universities and larger companies. They also objected to funding the program through a set-aside from other research budgets rather than as a separately appropriated program. This situation changed rapidly as the Bayh-Dole Act took off. By 1988, with the first reauthorization of the SBIR program, so many university-based small businesses were applying to the program that universities had mixed feelings and were reluctant to testify on either side.

As the supply of money grew, so did the number and quality of small high-tech businesses, and the percentage of American scientists and engineers working for them increased several times over. Now these businesses could begin to match the rhetoric of the program's early supporters. In later reauthorizations the program was changed to emphasize commercialization. Now, more and more countries around the world are developing their own versions of SBIR. All these developments show that changes in the antitrust laws created a climate in which small high-technology could thrive, but it was federal money, channeled through the SBIR program and other initiatives, that led to the rapid expansion of their numbers.

The Reagan Administration was the first to object that grants to individual companies might artificially create winners and losers in the marketplace. But it had no problem with subsidizing industries across the board through tax policy. Most of this effort went into reducing tax rates, but the Research and Experimentation Tax Credit of 1981 provided a partial tax credit for increases in industrial R&D. In the 25 years since that provision became law, it has never been made permanent. It has lapsed several times and is lapsed now, and five major changes have been made in its structure. Economists differ on the level of its effectiveness, especially given its tenuous nature, and on whether it targets the right research. Other countries have studied and copied it. For instance, Japan recently enacted an R&D tax credit that addresses some of the weaknesses in the U.S. provision, and other nations have enacted similar, but more generous, credits. If the law ever gave the U.S. a competitive advantage, it is now greatly diminished.

University research was one of the few areas where the Reagan Administration was willing to increase funding; federal funding of university research increased 50 percent during these years, and NSF funding doubled between 1983 and 1990.[10] In fact, science funding continued its upward trajectory until George W. Bush's second term, although it was increasingly weighted towards biomedical research. This growth in research funding contributed to the emergence of the modern research university, along with the Bayh-Dole Act and closer university-industry cooperation. Without these changes in the law, the current practices in university-industry cooperation would never have been possible. Without the increased funding, the huge increases in licensing, startups, and other novel relationships between industry and academia would not have occurred. Therefore, it is fair to say that the increase in research money to the universities played a catalytic role in emphasizing research, not unlike what the SBIR program did for small businesses.

Total Quality Management

Although it was not part of the DPR Innovation agenda, the Malcolm Baldrige National Quality Award, established near the end of the Reagan Administration, played a significant role in closing the competitiveness gap with the Japanese. It established a national standard for quality in business operations and promoted the DPR goal of facilitating labor-management adjustment to innovation. One irony of the U.S. decline in competitiveness in the 1960s and 1970s is that the Japanese looked to American mathematicians and engineers, including Joseph Juran and Edwards Deming, for the business methods that helped them transform their economy. Indeed, Juran and Deming began working with the Japanese only after they had failed to popularize their ideas in the United States. The Japanese took their ideas and turned them into an art form. They stress five key actions: focus on internal and external customers, focus on areas most needing improvement, involve all employees in quality and honor the highest achievers, and strive for continuous improvement. The Japanese named their highest quality award after Dr. Deming.

By the 1980s, some major U.S. companies were adopting the Japanese approach to quality. John Hudiburg, CEO of Florida Power and Light, decided to compete for the Deming Award and the Japanese obliged by creating a Deming category for overseas companies. Hudiburg imported Japanese experts to train his workforce in quality theory and methods. Frustrated after several years of trying to create a Presidentially awarded U.S. quality award in the private sector, in 1985 he proposed House of Representatives Science Committee Chairman Don Fuqua that he introduce legislation creating a U.S. equivalent of the Deming Prize; Hudiberg even provided quality experts to help write the statute.

With the untimely death of Commerce Secretary and close presidential friend Mac Baldrige in July 1987, the Reagan Administration began to support the legislation once its sponsors agreed to name it after Baldrige, whose industrial career had been in manufacturing. The bill quickly cleared Congress and Reagan signed it that August. The Malcolm Baldrige National Quality Program was established at the National Institute of Standards and Technology; its quality guidelines for manufacturing, small businesses, and service companies rapidly became an internationally recognized standard for quality that was emulated around the world, including in Japan. President Reagan underscored the importance of quality by personally presenting the first set of Baldrige quality awards. A federal quality program based on bringing Total Quality Management (TQM) to federal government activities was established the following year.

Standards Policy

In 1996, through the National Technology Transfer Advancement Act (NTTAA), Congress finally addressed the two final DPR areas: making the regulatory and procurement systems more efficient. Defense Secretary William Perry had undertaken an aggressive program of phasing out military specifications in defense contracting, replacing them, wherever possible, with voluntary consensus standards used in the private sector. Now the Defense Department could buy many off-the-shelf components and products that were much cheaper than products manufactured to unique military specifications. NTTAA extended this concept to all the government's purchases and regulatory activities: it is now required to use voluntary consensus standards wherever practicable, and government employees are encouraged to participate on the committees that write the standards. Since then, federal agencies have made substantial progress ending use of government-specific standards; they have made less progress in having employees help develop consensus standards and in identifying areas where the development of new voluntary consensus standards would benefit the government.[11]

Looking Back: The Value of the DPR

The Carter Administration proposed substantial changes in the way companies work together and the way that industry, government, and universities cooperate, hoping these changes would increase the nation's competitiveness posture. Carter did not remain in office long enough to put much of its agenda in place. But the Reagan Administration and its successors headed down a very similar path and eventually put in place much of what the Carter DPR had hoped for. The results exceeded expectations, at least temporarily, and let the nation maintain its supremacy in innovation. Other pre-existing factors were essential to the success of the U.S., including its meritocratic tradition, its relatively large and open domestic markets, its treatment of bankruptcy as a learning experience, and its traditional openness to talent from overseas. The DPR proposals and the Reagan era initiatives plugged gaps in the U.S. legal framework regarding innovation and built on the existing policies to place the United States in a unique position to blossom. Although that period of leadership eventually ran its course, it still provides a model for how the U.S. can lay the groundwork for further advances in innovation today.

TODAY'S CHALLENGE.
WILL THE U.S. LEAD OR FOLLOW
IN THE NEXT INNOVATION REVOLUTION?

Tremendous advances in communications technology, including the Internet and broadband, have irreversibly changed the world of innovation. It is now so easy to share work and to get data from anywhere that organizational boundaries have begun to blur. The U.S. no longer needs to focus on convincing sectors of society to work together closely because everyone in society is by definition much closer together. While individual companies, educational institutions, and governmental entities still need substantial internal restructuring before they can function as lean, innovative entities, this is no longer enough.[12] The U.S. must now think on a larger scale: How can the U.S. move beyond supply chains that connect together companies and their suppliers to value chains that add in the other parts of society who have an interest in a given problem, including government at all levels? To succeed, the U.S. must now shift its focus to a common language, a common vision, and ultimately to adopting a common way of doing business across industry, universities, and government as well as other pertinent parts of society.

Digitization and Data

The information component of innovation policy once again is king but in a way that participants in the DPR could never have imagined. The DPR focused on making sure that NTIS was collecting paper copies of as much government-generated and foreign technical literature as possible; now the key to future innovation is the availability, anywhere, any time, of huge amounts of data in digital information. Information that a decade ago would have taken days to assemble and understand, once in digital form, is available and useful almost instantaneously, thanks to search engines and data mining software. Groups of people no longer have to be in the same location to work together. Work can literally continue 24 hours a day; some tasks are now routinely handed off from one time zone to another. With digitization, even three-dimensional data can enter huge data pipelines made possible through fiber optics, and through advances in communications software and graphics. Today, if information is not in digital form, we see it as antiquated and clumsy; it presents a competitive disadvantage to both the company that does not digitize and to its customers.

How can the U.S. move beyond supply chains that connect together companies and their suppliers to value chains that add in the other parts of society who have an interest in a given problem, including government at all levels?

Take health care as an example. An article in the January 2005 on-line issue of the journal *Health Affairs* predicted that $78 billion a year could be saved by moving to electronic patient records in a network with open communication standards.[13] That $78 billion is the savings just from improved infrastructure. It does not include the impact of the innovations that become possible only after digitization. For instance, because digital x-rays contain more complete and more searchable data, they can probably be read by an experienced technician anywhere in the world with the same or better precision than a conventional x-ray can be read by the best trained personnel in the best hospital in the world. Therefore, President Bush's push for digital medical records makes sense and should be accelerated. The more quickly all sectors of the U.S. economy move to digital databases, the better.

Common Standards: Sharing Data in a Usable Form

Transforming data to digits and making broadband widely available are both necessary to enhanced competitiveness—but not sufficient.[14] The data must also be formatted and organized in a way that is generally understandable and easily retrievable. Consider a situation that arose late in 2000: the National Highway Traffic Safety Administration (NHTSA) linked 148 deaths and more than 525 injuries in the United States to separations, blowouts, and other tread problems of Firestone tires on Ford Explorer vehicles. Roughly 200 lawsuits were filed against Ford and Bridgestone/Firestone following crashes involving the tires. Over 6.5 million tires were recalled. The lawsuits and recalls cost the companies well over $1 billion. This was a tragedy of very large proportions for the companies and the families involved; today it could be minimized through the use of digitized data, collected in a usable form.

In 2000, the Ford Explorer value chain, the various organizations concerned with auto components, such as tires, at various points in their life cycles, acted as separate entities with their own standards and data sets. Ford and its supply chain manufactured and sold autos. Firestone and its supply chain manufactured and sold tires with identifying numbers that could be traced to factory and day of manufacture, but this information was not available outside the Firestone supply chain. The companies that took care of autos over the rest of their useful lives did not collect systematic data on tire wear. State motor vehicle departments oversaw semiannual safety inspections of autos, including tires, using their own state standards to measure how close tires were to failure on the date of inspection, but this data was not coordinated with the tire's history, and after the tire passed inspection, the data were not saved. NHTSA investigated the accidents and made recall decisions, using a fourth, independent data stream: data on the actual tire failures. As a final independent step, trial lawyers and the courts used another set of standards to redistribute huge amounts of company resources in an imperfect, after-the-fact attempt to make victims and their families financially whole. Data existed that could have prevented the tragedy, but it had been collected in suboptimal electronic form and was never made available to those who needed it.

Using the technology available today for data collection and analysis, the interested parties could collectively develop voluntary consensus standards that would provide a common set of rules governing automobile life cycles, including those of tires. We would then have a baseline on the properties of tires and components when they are manufactured, and the ability to trace and measure changes in the components throughout their useful life, and we would understand what is acceptable wear for the component. In addition to end-of-life safety, which is already monitored, we could detect abnormal wear problems much earlier in the component's life cycle and detect and address them before the first accident occurred. Since data would be available on all tires and other critical components, the scope of any recall could be carefully circumscribed, thereby avoiding damage from accidents and from adverse publicity. Since the standards of the inspectors and regulators would also be the standards of the manufacturers and repairers, corrective actions would be much easier to undertake. Standards development is yet another area where the Internet and software advancements have revolutionized the way we do business. Standards can now be developed on-line with participation from all affected parties in as little as three months; not long ago such a process would take years to complete.[15]

In making standards compatible, one key issue is addressing legacy problems. The Internet did an amazing job of connecting everyone, but it did not make sure that the computers on the ends of those connections spoke the same language. Most factories and their computer systems predate the Internet; when they were designed, no one was concerned to make their software systems compatible with those of their suppliers, customers, and other factories making the same product. A substantial amount of standardization and retooling has occurred but we still need product data exchange standards that will allow us to translate data from one design and manufacturing system to another. In 2002, Congress passed legislation to accelerate the development of these standards in key manufacturing sectors but the work has never been a top Bush Administration priority and has received only minimal funding.[16] Developing solutions to communications problems between software systems ranks with digitization and broadband implementation as a necessary precondition for unleashing the huge advantages made available by the Internet and related software.

Spreading Lean across the Business Community: Using Standards to Address Product Life Cycles

Firestone and Ford suffered both from not having common standards across a value chain and from the inability to measure products over their lifetimes. There are many other areas of the economy where thanks to the Internet and related software advancement, we now should be able simultaneously to save money and improve public health and safety by considering product life cycles. Consider the current building industry. It is a mixture of craftsmen, architects, engineering companies, suppliers, financiers, insurers, realtors, building code officials, and local regulators who form different teams for different construction projects. Each building has its own life cycle that involves utilities, remodelers, owners and operators, users, financiers, and insurers. Without standards that permit easy, relatively accurate measurement of the likely costs of construction decisions over a building's lifetime, builders will not pay a little more for improvements that will save the building's owners and operators a lot more in future years, thereby creating tremendous waste. For example, buildings often do not stand up under extreme conditions because first-time cost savings almost always trump life-cycle durability, safety, and energy efficiency. Highly efficient, but more expensive heating and cooling units or appliances are not used as often as they should be. And people constructing buildings rarely consider ease of repair or provide for the ability to upgrade easily to new technology.

Section 914 of the Energy Policy Act of 2005 requires the Department of Energy to contract with the National Institute of Building Sciences (NIBS) to upgrade building standards so all segments of the building sector can use them to design, construct, and operate high-performance buildings on a life-cycle basis.[17] To survey the current state of standards, NIBS has formed a High Performance Buildings Council that includes a wide cross-section of organizations interested in the design, construction, operation, and retrofitting of buildings over their useful lives. As a second stage, the department is to contract with appropriate standards development organizations to upgrade their existing standards and to fill in any gaps they identify that are not otherwise being corrected. The goal of the section is to provide a common standards language that permits all interested parties—from architects to realtors to banks and beyond—to make their decisions based on a combination of life-cycle costs and the ideal building attributes for a specific location. If this effort succeeds, it should force out much of the waste in the current system.

The standard should provide ways to coordinate building data with geospatial data. If building permitting goes digital, it will be possible to coordinate the data currently assembled for individual buildings by building permit offices with all other geographically organized data, including that from hundreds of databases coordinated through the United States Geological Survey.[18] Of course this requires appropriate security provisions, but the potential is enormous. For example, precise data on past flooding or windstorms could lead to informed decisions about the appropriate use of specific parcels of land. Historical weather records could be analyzed to determine whether adding a solar energy system, a heat pump, or extra insulation makes sense financially at a specific location. Data from the various transportation departments could help determine how to best use buildings and how much parking to add. Geological data could determine whether a ground source heat pump makes sense. Such data also has life cycle uses. For example, the baseline data on the size and construction of buildings collected by building permit offices, when combined with energy use records on individuals held by utility companies, could indicate which buildings are candidates for an energy upgrade. If the floor plans and information on construction materials now locked in paper form at building permit offices were available in searchable electronic form to first responders, emergency response to a fire or an earthquake could be more effective and timely.[19]

The regulatory world contains many examples of where the adoption of value chains using common standards over product life cycles could lead to dramatic improvements over current practices. Consider pharmaceuticals. U.S. decisions on drug efficacy and safety are based on a costly system of trials that usually occur before the product is used by the general public while data on drug use after approval is fragmented. Once the medical industry goes digital, a vast amount of actual use data potentially could become available to the entire pharmaceutical value chain including pharmaceutical manufacturers, researchers, physicians, pharmacists, users, and regulators, among others. Appropriate standards are much more difficult than in the Ford-Firestone example, because privacy of personal medical records is a paramount concern. If these problems can be surmounted, we will better understand dosage, drug interactions, and useful life of products. The digital availability of this information as in the case of Ford-Firestone also leads to the possibility of a complete revamping of the regulatory process where drugs can enter the market more quickly, where we have a more precise understanding of who is affected adversely by the product, and where product adjustments and recalls can be done more quickly and with less adverse economic effect.

The manufacturing sector has learned from experience that it usually takes ten or more iterations and several years to progress to a highly efficient, lean supply chain, but the initial savings are real and large. It will be at least as difficult to move entire business sectors—including their customers and regulators—towards lean operations on a life-cycle basis, but the benefits promise to be worth the effort. Moreover, the advantages to first movers will eventually cause companies to compete to modernize before their competition.

Outside of manufacturing, the lean movement in industry has begun in earnest but is still in its early stages. In March 2006, IBM Enterprise Business Services released the results of its survey of 750 of the world's top CEOs and business leaders; only 20% of CEOs feel they have been highly successful in restructuring but 65% of the 750 plan to change their companies radically in the next two years to respond to market forces. Two-thirds of their efforts are now targeted at innovations in their business models and operations and 61% fear that changes in a competitor's business model could radically change their industry. Of these CEOs, 76% consider collaboration essential and the rate of collaboration is highest in emerging markets. The CEOs also feel that competitive, dynamic suppliers are already available making their external obstacles to collaboration less severe than the internal ones.

Extending Quality to Other Sectors

Emphasizing quality, with a focus on data and customers, is an excellent way for companies to prepare for post-Internet innovation. Experience with the President's Quality Award (PQA) and state quality programs verified that the principles that have modernized so many American companies are equally applicable to other sectors of society. In 1999, the Malcolm Baldrige National Quality Award was extended beyond business as categories were added for education and health care. In 2005, a non-profit category was added that includes government. Now, every type of organization can aspire both to winning a Baldrige award and to meeting Baldrige criteria that set the standard for quality.

The Congressional sponsors of these changes anticipated that school administration and business functions would become much leaner. They were pleasantly surprised when some schools used Baldrige principles to empower teachers and students. The schools provided students with their educational goals and showed them the steps to take to reach higher levels in reading or mathematics. The students then worked towards achieving those levels, measured their own performance, and made much more rapid progress. If these practices could be spread more widely, they would trigger a major advance in competitiveness. Not only will students from schools practicing quality be better prepared to enter the workforce, but they will enter the workforce with an innate understanding of, and substantial experience in applying, quality principles to their daily work.[20]

Much of the waste in the educational process is related to the imperfect interfaces between schools at various levels and between schools and their students' employers. Often students need remedial education so to bring them to the point where they can do entry-level work at the next school level or for an employer. Equally wasteful is the repetition that high-performing students have to endure because a school cannot effectively evaluate what they learned at their previous schools. Ideally, schools should work jointly with their institutional customers—the organizations who employ or continue to educate their students—to develop common curriculum standards that meet their needs. Currently most school standards are one-size-fits-all, either regulations coming from third parties like departments of education or proprietary standards from testing organizations like the Educational Testing Service. While these regulations and standards have the potential to reduce some waste, they cannot be as efficient as standards that reflect the needs of the student's next school or employer.

> The ultimate goal in the U.S. should be to move from lean manufacturing to a lean society.

Here is an area where some of the Baldrige winners have made great progress. The University of Wisconsin-Stout has jointly developed curricula with several Wisconsin community colleges and works closely with several hundred potential employers on practical work experience and courses related to the employers' specific needs. This process enables community college students to earn a four-year degree that is relevant to their future employment and eliminates much of the need for future employers to offer training to new employees.[21]

The President's Quality Award (PQA) program and state award programs have shown great promise in bringing the values of the quality movement to the public sector. The advantages have been most apparent in times of crisis. Although we have no detailed studies yet, we do have strong evidence that organizations like the Coast Guard and the Strategic Petroleum Reserve, which had adopted these practices, were much better prepared for Hurricane Katrina and much more successful in their response than organizations like FEMA that had not adopted modern business practices.

Unfortunately, in 2001, the Bush Administration chose to change the PQA. Now, instead of measuring an agency's performance against Baldrige criteria, it measures progress in achieving the administration's top-down, bureaucratic goals for the agency.[22] But the non-profit Baldrige category promises a new beginning.

This year the program will test run its non-profit categories using the winners of state quality awards (SQAs). The logical next step would be to establish quality awards in the various agencies based on Baldrige criteria and to maintain the prestige of the Baldrige Award by allowing only the winners of agency quality awards to compete for the Baldrige. NIST should also consider establishing a quality subcommittee within its Interagency Standards Committee to help coordinate agencies' efforts to redesign for quality.

Common Work Culture

The ultimate goal in the U.S. (as well as elsewhere, as appropriate) should be to move from lean manufacturing to a lean society. The extension of the Baldrige award criteria to all segments of the economy gives the United States the chance to move to the next level of social capital: a common culture and a common set of principles for interacting professionally with others across the entire society. If American universities, government, and industry all adopted the common commitment to serve their customers, many of the barriers of dealing with each other would disappear over time, and the U.S. would have a definite advantage over institutions abroad that are less responsive. The U.S. would move beyond the goal of running government efficiently, to using government to promote public health and safety and the common good in harmony with the private sector. Rather than being threatened by government, business would participate with all interested parties, including regulators, in developing common standards that serve as a common basis for doing business and meeting public needs.

If done right, regulation would move from quality control to quality, in an analog to manufacturing's revamped approach to quality. Just as manufacturing defects in a six-sigma company are largely a thing of the past, violations of health and safety standards would also become highly unusual, ending the need for after-the-fact inspections and recalls. Regulation designed in harmony with manufacturers becomes just-in-time regulation applied at the appropriate time in the least obtrusive way. Under this scenario, government programs designed to serve industry also will need a revised mission. The Manufacturing Extension Partnership (MEP), described earlier, was set up to serve small businesses by helping them modernize their manufacturing processes and layouts. A post-Internet MEP, at minimum, will help small businesses serve their customers by helping them to digitize and to qualify for the most sophisticated supply chains. Potentially, the purpose of MEP will be to help bring about the lean society's value chains, including helping government agencies that fund or regulate small businesses go lean themselves.

Relatively rarely does industry turn to universities for help with its research problems. Despite the huge increase in the talent they now enroll, universities currently perform only 1.7 percent of industrial research, at a time when corporations are contracting out virtually anything that can be done cheaper and better elsewhere. This percentage has barely changed over the last 50 years.[23] Industry and universities both offer their explanations for this situation, but the main reason is the gap between the two cultures. Universities prize curiosity-driven research; corporations want research that will solve specific problems and improve the bottom line. Industry is dealing with quarterly earnings and shorter and shorter product cycles. Even in their activities that ostensibly serve industry, universities tend to place a higher priority on publication than on commercialization, and on the academic calendar than the business calendar.

If universities adopt quality and the lean philosophy, the customer will become the king and the organization will constantly look for ways to better meet the customer's needs. Those universities that wish to attract a larger share of research funding will realize their primary competition is outside academia. They will learn why industry funds this work. To compete, they may need to become just-in-time suppliers of applied research, offering service equal to that of the businesses now supplying the research—even if this means structural changes. Just as companies that have mastered quality and leanness often become suppliers of choice and grow rapidly, the first universities that master these concepts will have an immense competitive advantage over other schools; they will also gain access to a largely untapped source of research funding that is several times what government can and will spend on university research.[24]

Equally great potential for change exists in the medical sector, if digitization and improved standards can pull all parts of the medical value chain together. X-rays are just the beginning of how digital enhancement will improve capabilities to analyze data and deliver better care. New value chains, such as those connecting sensors, emergency technicians, visiting nurses, doctors, and emergency rooms, are already beginning to allow patients to stay in their homes longer and will, over time, have a dramatic impact on Medicaid costs. Other medical costs will join pharmaceuticals in facing downward pressures as the Internet helps us move towards a worldwide standard of care and increases consumer choice in the medical services.[25]

CURRENT INNOVATION PROPOSALS

In December 2004, the Council on Competitiveness, an organization of presidents of major universities and CEOs of major companies, put forward a ten-point plan entitled "Innovate America" which focused on education and worker retraining, increased appropriations and tax breaks for research, and creating Innovation Extension Centers to strengthen manufacturing and investing in the next-generation Internet. The report also dealt with social capital, though it offered more concepts than details. Among the Council's suggestions were these: reduce the cost of tort litigation by one half, develop a White House innovation strategy, develop new metrics to understand and manage innovation more effectively, develop best practices for setting collaborative standards, and establish standards for an integrated healthcare system and expanded electronic health reporting. Based on this report, bipartisan legislation has been introduced in the

Senate that would authorize increased spending for federally-funded research and would have the National Institute of Standards and Technology coordinate federal manufacturing initiatives.[26]

The American Electronics Association subsequently issued a report, "Losing the Competitive Advantage? The Challenge for Science and Technology in the United States," which made several suggestions: lower barriers to immigration for high-skilled workers, enforce intellectual property worldwide, improve education, increase the same research programs as suggested by the Council on Competitiveness, and provide incentives to promote broadband and cellular penetration.[28] In late 2005, the National Academies followed with a report, "Rising above the Gathering Storm" that provided an expanded list education reform proposals, and called for increased R&D funding and related tax breaks, as well as many of the reforms advocated by the American Electronics Association.

Legislation to implement many of the National Academies' recommendations has been introduced by Senators Lamar Alexander, Jeff Bingaman, and Pete Domenici in the Senate and by Congressman Bart Gordon in the House of Representatives. The president's budget for fiscal year 2007, released early in 2006, includes a few of the research and development funding proposals, but largely pays for them through cuts to existing programs in manufacturing and research and development. This was followed by a House Republican competitiveness initiative that includes the president's research and development funding increases, selected tax incentives, incentives for improved technology in the healthcare system, and changes in tort law including making it easier to disbar trial attorneys. Later, a second set of House Republican bills tried to accomplish some of the National Academies' goals through amendments to existing programs.

Since all these initiatives are in the early stages of the legislative process, it is unclear right now whether legislation to authorize competitiveness will be enacted in 2006 or what final form it might take. Initial signs from the appropriations committee indicate that programs related to competitiveness would be slightly better funded in the aggregate compared to recent years. This year's experience to date also reconfirms that it is easier and quicker to fund legislative solutions to perceived problems than to update the legal framework. Yet, as the U.S. moves forward, it will have to do both, if it is to reestablish a strong competitive position. The U.S. will have to think deeply about how it can take advantage of new opportunities and about the related changes these opportunities will require in law, regulation, and the way the approaches its jobs and its customers.

NEXT STEPS AND COMMON VISION

Is a common vision, leading to a lean society, possible today? At the local level, clearly it is. Municipalities or clusters that embrace digitization and telecommunications advances and that promote quality throughout their communities clearly will be highly desirable places to carry out business and will be able to respond to opportunities quickly and with a united voice. Local governments have a major impact on local economic development; their leaders rise and fall according to how well the local economy is doing. This is the governmental level at which economic reality comes closest to being the same as political reality. Most major companies plan to restructure dramatically in the next couple of years; this trend will only accelerate as the pressures they feel reverberate through supply chains. Communities will come to understand that lean companies will need lean research partners and lean government in addition to lean suppliers. Those who learn this first will have a tremendous competitive advantage and the local communities that host their competitors will quickly follow their leads.

It is harder for the federal government to reach consensus on major policy changes; generally it can make big changes only in the direction of public opinion. When industry progresses to the point where external inefficiencies cause more problems than internal inefficiencies, consensus for change at the federal level will develop. Then, national politicians will pay attention and be able to act. Will this happen in the United States sooner or later than overseas? We don't know. As a nation, the United States still has major advantages. It is a country that thrives on challenges, and does its best at times like the present when it feels threatened. The U.S. is also clear on the general direction it must take and have begun to prepare for the time when federal action is possible. As a representative democracy the U.S. moves more slowly than authoritarian countries but the U.S. has an advantage: ideas that make it through the legislative process tend to be highly refined and well-reasoned. Just as in 1979, as the U.S. begins to lay the groundwork for the next innovation revolution, it is starting a process that will twist and turn and will take more than one administration to implement. The U.S. will have less time than in 1979, because innovations become international much more quickly than ever before, but the U.S. also has tools to act more quickly than it did in the 1980s and 1990s. The process it is beginning will yield impressive, but unpredictable results. To make sure that efforts are both timely and world-class, a coordinated effort will be necessary.

We invite reader comments. Email <editors@innovationsjournal.net>.

1. In 1968-69, the Industrial Research Institute conducted a workshop entitled Research-on-Research, funded by the National Science Foundation, that recommended establishing one or more university research centers. No university 'centers' had emerged through the early 1970's. In the meantime, 'Industrial Innovation' gained attention on the national scene via the 1971-72 publication of the Arthur D. Little 'Charpie Report,' sponsored by the U.S. Department of Commerce. The

report called attention to shortcomings in the U.S. system of government policies and to industrial management practices that threatened U.S. economic progress because they failed to understand and appreciate the social and economic effects of industrial innovation. Under President Nixon, a White House study of the problem discussed in the Charpie Report was launched. Three initiatives emerged: The Experimental Technological Incentives Program (ETIP) in the Department of Commerce; the Experimental Research and Development Incentives Program (ERDIP) in the NSF; and the National R&D Assessment (RDA) program, also in the NSF. Throughout the 1970's, the RDA program and its successor, the Division of Policy Research and Analysis, supported academic research on the nature and effectiveness of industrial R&D/innovation management practices, with an eye toward assessing the impact of government policies (e.g. on patents, taxes, the environment, and the SBIC) on 'the rate and direction of industrial innovation' in the U.S. By 1975, this program had established a liaison between the IRI and the NSF but by 1978, it was forced to close down for financial reasons. <http://cims.ncsu.edu/history.php>.

2. The DPR was unveiled on October 31, 1979, at a joint hearing of four committees: the Senate's Committee on Commerce, Science and Transportation and its Select Committee on Small Business, and the House Committees on Science and Technology and on Small Business. The hearing transcript, including administration submissions, is printed as Committee Print No. 69 of the Committee on Science and Technology for the 96th Congress and is generally available at federal depository libraries.

3. See the hearing record on the Uniform Science and Technology Research and Development Utilization Act, House of Representatives Committee on Science and Technology publication 86 for the 96th Congress and House Report 98-983, Part I.

4. While most commentators feel that Bayh-Dole was probably the catalyst for rapid growth, Mowery et al. argue that it is impossible to know for sure because the biotech industry was emerging at the same time. See David Mowery, Richard Nelson, Bhaven Sampat, and Rosemary Ziedonis "The Effects of the Bayh-Dole Act on U.S. University Research and Technology Transfer," Chapter 11 in Lewis M. Branscomb, Fumio Kodama and Richard Florida, editors, *Industrializing Knowledge: University-Industry Linkages in Japan and the United States* (Cambridge MA: MIT Press, 1999).

5. The anonymous Economist article is reproduced at the end of a May 24, 2004 speech by Senator Birch Bayh at the National Institutes of Health at <http://www.autm.net/aboutTT/aboutTT_bayhDoleAct.cfm>. But the law has its critics. Other publications, including an anonymous 2005 article in Fortune, entitled "The Law of Unintended Consequences," have lamented the resultant changes in universities.

6. See <http://www.aurp.net>, the website for the Association of University Research Parks, for Jackie Kerby-Moore's March 2, 2006 presentation entitled Research Parks: Cataloging America's Competitive Edge and for more in-depth information on the growth of research parks at universities and government laboratories.

7. The Department of Energy is the exception in the use of CRADAs. It was not interested in having CRADAs apply to its National Laboratories in 1986 or, after the law was changed in 1989, to permit National Laboratory CRADAs. The department's rules for implementing CRADAs have never permitted DOE CRADAs to reach their potential.

8. National Science Board's Science and Engineering Indicators.

9. The 1988 Trade Act also established the important Advanced Technology Program (ATP), which was designed to address the problems innovative companies have in finding patient capital during the technology development stage of the innovative process. [What is patient capital? Investors who are willing to wait?] A highly successful pilot program under George H. W. Bush, it grew dramatically during the first two years of the Clinton Administration, only to be reduced to a fraction of its original planned size and placed under constant attack as a "corporate welfare" program once the Republican Party gained control of Congress in 1994. The closed DPR recommendation to ATP was to aid small businesses through state or regional cooperation for economic development. Ironically, state technology programs became strong enough to be effective partners just a few years later, but by then the political window for amending the program had closed. I believe that if we in the legislative branch had been able to move to the DPR formulation, the program would have developed

a national constituency like that for the MEP program and it would no longer be in political danger.

10. National Science Board's Science and Engineering Indicators.

11. Under the National Technology Transfer Advancement Act, the Secretary of Commerce is required to report to Congress annually, on both government use of standards and federal employees' participation in developing voluntary consensus standards.

12. I use the word lean in this context in the same way that James P. Womack and Daniel T. Jones use it in their *Lean Thinking* (New York: Free Press, 2003). I argue that the same basic principles these authors apply to manufacturing can be and are being applied to other aspects of U.S. society.

13. See<http://content.healthaffairs.org/cgi/content/full/24/5/1138>. While some experts think the journal's estimate of $75,000 annual savings per doctor is too high, huge savings are clearly possible.

14. The most recent Organization for Economic Cooperation data indicate that broadband use is growing rapidly worldwide; in just the second half of 2005, it grew by 16 percent. The U.S. has the largest total number of broadband subscribers but ranks 12th in per capita broadband use (16.8% penetration as compared with world leader Iceland's 26.7% penetration). The number of businesses and consumers with the option to buy the technology is also expanding rapidly. See <http://www.oecd.org/> to view December 2005 OECD Broadband Statistics.

15. This information comes from private discussions with senior executives at the American Society for Testing and Materials.

16. Public Law 107-277 established a four-year program that would have led to the development of product data exchange standards for each major sector of the manufacturing and construction industries. The program did not go forward because appropriations to carry it out were not provided.

17. Public Law 109-58, Section 914, August 8, 2005.

18. The U.S. Geological Survey plans to have a searchable data base for geospatial information functioning by June 30, 2006. For a description, see National Geospatial Programs Office: A Plan for Action <http://pubs.usgs.gov/of/2005/1379/>.

19. In 2001, the federal intergovernmental committee that studies mapping adopted the national grid as the standard for federal agencies. Four years later, FEMA's failure to have software for geospatial mapping in its Emergency Operations Centers hampered its response to Hurricane Katrina victims. See "Which Way to the National Grid," *National Journal*, April 29, 2006, pp. 59-60.

20. Two school systems have been leaders in the effort to empower students: those in Pinellas County, Florida and in Chugash, Alaska; the latter was a 2001 winner of the Baldrige Award. Its experience is described on the award's website: <http://www.quality.nist.gov>. Chugash even abolished grades in favor of having students work to meet standards that are often more advanced than state graduation standards.

21. Information on Wisconsin-Stout also can be found on the Baldrige website: <http://www.quality.nist.gov>.

22. See "OPM links President's Quality Award to Bush management agenda" <http://www.govexec.com/dailyfed/0202/021502m1.htm>.

23. Science and Engineering statistics in this article are derived primarily from the National Science Board's Science and Engineering Indicators.

24. Through its University-Industry Demonstration Partnership, the Government-University Industry Research Roundtable (GUIRR) of the National Academies is working to remove barriers to university-industry cooperative research by sharing information on best practices and developing such aids to cooperation as the TurboNegotiator data base. See:
<http://www7.nationalacademies.org/guirr/The_Federal_Demonstration_Partnership.html>.

25. See Really St. Elsewhere," *National Journal*, May 13, 2006, for a discussion of the role health insurers play in lowering costs by internationalizing routine surgery.

26. For the report text, see: <http://www.compete.org/nii/>

27 For the report text, see: <http://www.aeanet.org/Publications/idjj_AeA_Competitiveness.asp>.