Expediting Serendipity:
Building an Innovation Ecosystem

by Shirley Ann Jackson, Ph.D.
President, Rensselaer Polytechnic Institute

Detroit Economic Club
Detroit, Michigan
Thursday, October 8, 2009

I am delighted to be here, and I am grateful that the Detroit Economic Club gathered this country's leaders to the June National Summit to work toward consensus on our greatest challenges. To focus the Summit on Technology, Energy, Environment, and Manufacturing was particularly apt.

Painful as it has been, the Great Recession has exposed many economic fallacies, including the idea that consumer spending, finance, and service industries, alone, will guarantee the economic vitality of the United States. Clearly, we must focus on more substantial sources of prosperity — especially technological innovation, and our capacity to translate innovations into commercial or social use, domestically, and to export them around the world.

Today, I want to consider the steps we must take to innovate at the pace and scale required, not only for recovery from the current economic crisis, but to lay a foundation for true global competitiveness and leadership. This foundation must rest in a self-sustaining innovation ecosystem, where new industries and enterprises of all kinds naturally germinate and grow.

Detroit had such an ecosystem at the beginning of the 20th century. There was fertile ground provided by the sophisticated machine tool and carriage industries already present here. Combined with the brilliance of Henry Ford, and the world's most diverse and productive workforce, that ground yielded an automobile industry so dominant, it became synonymous with the United States in the world's eyes. How, then, do we create an equally favorable environment for the 21st century?
To answer that question, we must look at the key players in any innovation ecosystem and its key elements.

Like its natural equivalent, an innovation ecosystem depends on an intricate set of relationships to succeed. Today, academia, industry, labor, the financial sector, and government all contribute significantly to innovation. However, at the points of intersection between them, the interplay is often insufficient or counterproductive. It is here where promising ideas may be lost — and where new policies and new approaches are essential.

If we examine the elements that emerging enterprises or innovations require — strategic focus, idea generation, translational pathways, and financial,

infrastructural, and human capital — we can readily see the gaps that must be filled before we can truly call the system we already possess an ecosystem.
Let us begin with strategic focus. It is clear that, as a society, we face two great challenges that demand transformational technologies: first, energy and environmental sustainability, and, second, health care.

It is instructive to consider what is required to create a sustainable energy system. We obviously need an overall national strategy, or roadmap. Such a strategy and action plan were laid out, with regard to energy, by the U.S. Council on Competitiveness in its Energy Security, Innovation, and Sustainability initiative, an initiative I was privileged to co-chair.

First, we must find new, renewable power sources and storage technologies, such as advanced batteries. Second, we must find ways to use existing energy sources with less impact, for example, by solving — finally — the challenge of carbon capture and storage for fossil energy sources. Third, if the future of transportation is electrical, we, also, need to determine where all this electricity is going to come from, and what physical, economic, and regulatory infrastructure is needed to support this future. Finally, we must develop two forms of intelligence in our national electrical grid — the ability to deal with multiple types of energy sources, including the intermittency of renewable energy; and the ability to support smart appliances that draw electricity during low-demand periods.

In other words, an explosion of new industries is required to answer the questions of energy security and climate change. Our economic opportunities and grand challenges happen to be one and the same.

Health care, as well, can benefit from new technologies that could generate new industries. These include enabling technologies for the mitigation and cure of diseases, which may soon include revolutionary ways to use biological processes to manufacture new treatments. Technology may soon make genome sequencing and drug development so affordable that personalized medicine will become the standard. Our health care system, itself, requires a range of technological innovations simply to lower its overall costs while spreading its benefits to all Americans. This includes, of course, electronic health records, and new ways to monitor patient health conditions in real-time, or to connect patient health information to broader data bases, and to research results, in ways that allow prevention, and/or mitigation of disease.

Ultimately, however, our health care system, like our energy system, is an expression of our basic values, and our vision of what a modern society should be. The federal government has multiple roles that can drive or influence innovation. It is the key decision-maker, policy-setter, investor, regulator, consumer, end-user, and endorser across multiple fronts. In particular, the federal government has both regulatory and incentive tools at its disposal. The Environmental Protection Agency, for example, recently has announced that it will regulate greenhouse gas emissions from power plants — an important step, although, ultimately, we must have a full climate change agenda that meshes with an international agreement.

The government has, as well, incentives that might spur the development of essential innovations if used more frequently. It can use funding, for example, to steer university research towards our key challenges, as is intended with the new Advanced Research Projects Agency for Energy (ARPA-E).

The federal government, also, can encourage industry to innovate in key areas by awarding more and larger grants to high-tech start-ups through mechanisms such as the Small Business Innovation Research Program. Other incentives include tax policies to encourage industry-based research. Our current federal Research and Experimentation (R&E) tax credit still is not permanent, and by international standards, its incentives are underwhelming. A sensible expansion might encourage more research to be done collaboratively between companies, or between industry and universities. An R&D-linked (or overall) lowering of tax rates might create more patient capital for long-term, larger-scale projects — focused on both basic research and infrastructure development.

The government can use its own vast purchasing power to move us forward. The U.S. Department of Energy has offered an interesting model by sponsoring a $10 million prize for an energy-efficient LED light bulb design — and, the chance to compete for even more valuable federal contracts. Procurement can be used to accelerate the turnover to advanced-technology vehicles.

The key element of our ecosystem is idea generation. Game-changing ideas tend to arise out of basic research, which pushes the boundaries of human knowledge. Universities are critical players here, because basic research dovetails magnificently with their educational mission. The primary contribution of universities to our ecosystem is the education of bright, motivated people, who ask questions that may take decades to answer. The endpoints of basic research in terms of commercial technologies often cannot be envisaged — even by the researchers themselves. Yet, history shows that out of such open exploration, thriving industries are born. It was basic research at the Defense Advanced Research Projects Agency (DARPA), for example, that gave birth to the Internet. Another example is provided by the sharing of the 2009 Nobel Prize in Physics by two researchers who developed the charge coupled device (or CCD), a digital sensor, which converts light to electrical signals, and allows images to be gathered and read out in a large number of image points, or pixels. CCDs are widely used in cameras, intra-body imaging in medicine, and in astronomy. The other recipient of the prize calculated how light could be transmitted over large distances by ultra-pure optical fibers. Without this breakthrough, there would be no true Internet — no World Wide Web. Unfortunately, in recent years, across multiple sectors, we have stinted basic research to meet shorter-term goals. Corporations increasingly have found high-risk, long-term investments difficult to justify — particularly given investors' interest in quarterly results.

Government agencies, also, have focused, increasingly, on safe, near-term bets, preferring to fund incremental projects proposed by researchers — well into their careers, with a history of success. This means that the median age at which researchers are offered grants is rising, which is not an attractor for scientists at early stages of their careers.

This hardly makes sense in a world that needs world-changing discoveries and transformational technologies, which do not always emerge from the most senior researchers. Basic research is an intergenerational pursuit. It was a Rensselaer undergraduate who, last year, invented an artificial cellular organelle called the Golgi Apparatus, which builds complex sugar molecules. Artificial Golgi show great promise for the manufacture of sugar-based medicines, including a safe, synthetic version of the blood-thinner heparin, one the most widely prescribed drugs. After more than 80 people died from contaminated, animal-derived heparin, Rensselaer professor Robert Linhardt and his group helped to uncover the source of the contamination. Shortly thereafter, Dr. Linhardt announced the successful creation of bioengineered synthetic heparin. This result came after decades of work on polysaccharides by Dr. Linhardt and his colleagues. This work was clearly intergenerational.

There are other examples. At Rensselaer, alone, researchers have created the darkest material ever made, produced a paper battery, and attacked the flu virus, for the first time, on two flanks — at both its H and N proteins. These discoveries may transform or create entire industries in ways that we cannot predict. History is full of startling juxtapositions of initial purpose and eventual application — such as microwave technologies developed for missile detection which, now, are used in cancer treatments.

When we fund basic research, we are funding serendipity. Even a sober, frugal, post-recession United States must invest in serendipity, because without it, there is no vitality in the innovation ecosystem.

A robust innovation ecosystem requires, as well, translational pathways that bring discoveries into commercial, or societal, use.

The protection, regulation, and exploitation of intellectual property are one example. There always have been university discoveries that have been commercialized, such as Gatorade. The Bayh-Dole Act sought to spur this further by giving universities ownership of the results of their federally funded research, and the right to patent and license them, and to share royalties with the researchers. Through the deliberate exploitation of their intellectual property, modern research universities are linked to the marketplace more strongly than ever before.
Bayh-Dole has been successful, spinning off thousands of new enterprises based on university patents. Yet there are costs in converting the work done at universities into private property. University of Michigan Law School Professor Rebecca Eisenberg has warned of a potential "tragedy of the anti-commons," if the increasing proliferation of patents in upstream research makes it difficult for researchers downstream to access the permissions and information they need to build on previous innovations.

Within that context, universities may view the question of which discoveries should be kept proprietary, and which should be open-sourced, as a matter of the ethos of science. Data must be, and are, shared openly, for easy collaborations between scientists. Computer scientists at Rensselaer are creating a Semantic Web platform which will compile scientific data on an unprecedented scale from every possible source, and make it accessible, for the first time, to citizens, as well as scientists, all over the world. The government may consider the same question as a matter of policy to spur innovation — possibly granting an automatic exemption to patent law — for the use of proprietary intellectual property in noncommercial research at a university.

An exciting example of open-sourcing in current science is that of the BioBricks Foundation, which offers to students, and others, information about standard DNA parts that encode for key biological functions, which they can use to bioengineer new organisms.

Our innovation ecosystem has much to gain if universities fling open such storehouses of knowledge. At the same time, we must be aware that some technologies must be handled carefully. An example is provided by dual use technologies which could have both commercial and national security uses, or could have both beneficial and non-beneficial uses. Using BioBricks, amateur biologists conceivably could employ plug-and-play DNA parts to accomplish such socially beneficial goals as consuming greenhouse gases or producing a renewable fuel, or to engineer micro-organisms for use as weapons by terrorists. Together, we need to ensure an appropriate focus on the ethical issues embedded in technological innovation, and to create new mechanisms for vigilance to balance security issues with the free exchange required by expediting serendipity.

Industry, too, must beware of controlling its intellectual property so jealously that it stifles innovation. We also need to consider a central issue concerning intellectual property in the biomedical field: the fact that pharmaceutical development, including clinical trials, is so expensive that promising treatments for certain diseases, which disproportionally affect certain groups or poor nations, often never see the light of day. Voluntary, shared patent pools for the developing world, or for certain diseases, may be one answer. The shared royalties may be smaller, but the outcomes are greater. New kinds of partnerships for drug development between industry, universities, and nonprofits may be another. Expanding government incentives for the sharing of intellectual property for humanitarian purposes may be a third.

Intellectual property is not the only translational pathway. Many patents emerging from university laboratories are licensed to start-ups, often formed by the researchers themselves, and these fledgling businesses may lack survival skills for the world of commerce. In the wake of Bayh-Dole, business incubators were formed around the country to assist such start-ups. Unfortunately, the standardized services such incubators offer — accounting, legal advice, a fax machine and desk — while necessary, may not be adequate to launch breakthrough technologies in fields such as synthetic biology or nanomaterials.

A robust innovation ecosystem must provide the financial, infrastructural, and human capital to support the development and exploitation of promising new technologies.

We clearly need a new financial model for start-ups, as venture capitalists increasingly prefer to invest in less risky, later-stage enterprises, and entrepreneurs refer to a widening "valley of death," when no financing is obtainable. Large corporations, too, are not always willing to fund the development of undergirding technological breakthroughs that offer them no exclusive competitive advantage. Rensselaer professor Jonathan Dordick and his partners, for example, have created biochips, cell cultures that allow a rapid screening of the potential toxicity of drug candidates without the need for animal testing. This is a game-changing technology, yet the chemical and pharmaceutical businesses that have the most to gain from it are not investing in it, because its applicability is too broad. Instead, federal grants are supporting the start-up company, which the researchers have formed to scale up and commercialize the technology. Our innovation ecosystem may well require more such early-stage government support for potentially transformative technologies. An example in the energy field, proposed by the Council on Competitiveness ESIS Initiative, would be the creation of a National Clean Energy Bank to provide insurance and other risk management or credit enhancements, such as loan guarantees, for the construction of large infrastructural projects, such as geological storage for carbon emissions.

Sometimes, however, businesses do support even the most broad-based innovations by creating consortia. For example, two companies hoping to validate their method of testing the cardiotoxicity of new drugs are trying to launch a consortium.
We need Centers for Innovation Management which can be university-based organizations that offer expertise targeted by industry. These centers should be able to advise start-ups on the particular market mechanisms and regulatory hurdles each will face, worldwide.

Moreover, these Centers should be capable of developing the essential connections that network a technology into the innovation ecosystem — connections between inventors and entrepreneurs — and between entrepreneurs and research facilities, established companies, and markets around the globe. Such Centers ought to be powerful enough to advocate for emerging technologies with both governments and leading corporations. This suggests that universities, which previously considered each other competitors in technology transfer, might join forces to magnify their voices — and create platforms that allow them to work in concert.
Equally important is the physical capital that allows new technologies to be improved and scaled for the marketplace — facilities for continuing research, for the prototyping and testing of new technologies, for the development of advanced manufacturing processes. Emerging technologies in nanoelectronics or bioengineering may well demand the kind of computational power, instrumentation, robotics, and clean rooms that no single company can afford.
The question is — where should such commercial work occur? Universities have facilities which some companies rely on for early-stage commercial explorations.

Yet the issue of such work on university campuses is fraught with potential conflicts. It may well interfere with the teaching and research of faculty and with the university core mission to educate students. A university cannot be turned into an early-stage factory for businesses that move in lock-step with their interests and desires.

What are the alternatives? We need to develop infrastructure that can be shared by nascent industries as a new kind of capital to undergird innovation. Such infrastructure could be based at a university — with appropriate safeguards — to exploit intellectual property coming out of university research, to support applied research, or to provide critical infrastructure for small and large companies. The Rensselaer Computational Center for Nanotechnology Innovations (CCNI) offers a potential model. It is located off our main campus, in the Rensselaer Technology Park — a business park owned by the university. A joint project of IBM, New York State, and Rensselaer, it not only hosts one of the world's most powerful university-based supercomputer, it allows companies of all sizes to perform research, and to tap the expertise of Rensselaer scientists who would otherwise be inaccessible. Yet, the CCNI provides immense computational power for Rensselaer faculty use in basic research. This is enabled through a broad-band connection between the campus and the technology park.

Such physical capital need not be exclusively university-based. It could be in proximity to our national laboratories, or be developed by industry consortia. Sematech, the semiconductor consortium formed in 1987, with the support of the U.S. Department of Defense, offers an interesting model. It was created to enable the development of manufacturing processes crucial to the industry that no single company could finance. The consortium laid out a semiconductor research and development roadmap, which has been followed to position the U.S. as a leader in the semiconductor industry in advanced chip design and manufacturing.
To rebuild our industrial base, what is required in the short-term is to further develop manufacturing processes which link information systems to physical processes — using sensors, actuators, and other key technologies — as part of a broadly intelligent advanced manufacturing system.

An example might be joint federal and state-sponsored regional advanced manufacturing centers to drive technology and best practices through the supply chain. These could be modeled on the NIST Manufacturing Extension Partnership Program.

The most crucial of capital required for our ecosystem is human capital. Clearly, the nationwide crisis in our manufacturing sector, which has lost 5 million jobs since 2000, has created a skilled, but underemployed, labor force eager to rebuild the nation's industrial base. In the longer-term, we can build upon the road-mapping exercise undertaken by the National Science Board in robotics — to identify important cutting-edge technologies, relevant across multiple fields, that show the most promise for evolving manufacturing in key fields, such as health care and energy, and lay out the facilitating framework for deploying such technologies in the United States.

Yet the demands of advanced manufacturing require that every player in the ecosystem — universities, government at all levels, and businesses — contribute to a comprehensive education and retraining effort for our labor force in new technology development and use. Possible tools might be to make worker training benefits portable, and to give private industry a stake in creating a pipeline of workers through tax incentives to U.S. companies.
We, also, need to look further into the future, and to understand that there is a Quiet Crisis brewing in the gap between the innovation ecosystem's need for scientists, engineers, and technologically skilled professionals, and our failure to produce them. Our colleges and universities are not graduating enough scientists and engineers to take the place of those who are now retiring, and we are doing a particularly poor job of recruiting the underrepresented majority of women and minorities.

Clearly, we must work together to improve mathematics and science education from the very beginning of our children's educational careers, to help them understand the excitement of discovery and innovation, to nurture them — and to lead them to advanced study — those who will sustain our innovation ecosystem through the next generations. We also need to work harder to retain high talent from abroad, especially those obtaining advanced degrees in science and engineering from American universities.

Ultimately, however, the true first step towards creating an innovation ecosystem is to acknowledge the powerful economic opportunities to be found in our grand challenges, if we confront them boldly. Michigan may well find itself fertile ground for innovation once more, as its pressing need to restructure the automobile industry — together with its great research universities, and a high concentration of engineers and skilled workers — draw advanced battery makers and other green manufacturers here. We simply need to develop the right policies to encourage and to sustain their growth.

Complexity theorist W. Brian Arthur has compared the evolution of technology, rather beautifully, to a coral reef that "builds itself from itself." The work of brilliant individuals adds substance to that reef. But, we all live within its shelter, and each of us, in our own way, must contribute to it, if it is to be as rich and diverse and fruitful as we know it can be.

Thank you.

Source citations are available from Strategic Communications and External Relations, Rensselaer Polytechnic Institute. Statistical data contained herein were factually accurate at the time it was delivered. Rensselaer Polytechnic Institute assumes no duty to change it to reflect new developments.