



Rensselaer

Office of the President

“Educating and Innovating Our Way to a 21st Century Manufacturing Economy”

City Club of Cleveland

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I am delighted to address this distinguished forum. This afternoon, I would like to offer a few thoughts about freeing our newspaper headlines from a particularly unhappy phrase—the “jobless recovery.”

There are many diverging ideas about what should be done immediately for the nation’s 15 million unemployed, and a number of them are contained in the jobs bills passed in the House the Senate in the last week. However, there is, or should be, remarkable consensus on the long-term solution: investment in scientific discovery and technological innovation, and their translation into new enterprise.

In 1987, economist Robert Solow was awarded the Nobel Prize for his work demonstrating that technological progress is crucial to economic growth. Indeed, after World War II, the United States emerged as the world’s greatest economic power, largely because it became the world’s greatest scientific and technological power-- thanks to an energetic wartime partnership among industry, universities, and government in research and development. This was extended and institutionalized after the war through government

support of basic research in universities, and advanced training of students in science, mathematics, and engineering. There was concomitant investment and support from, and to, industry, and the creation of robust university/government/industry partnerships in research and development, and education.

Over and over during the past sixty years, breakthrough scientific discoveries have led to new technologies, which have created new industries, which have generated millions of good jobs.

Today, emerging fields such as renewable energy, nanotechnology, and biotechnology promise to improve many lives, and spur substantial economic growth. In 2008, the United Nations Environment Programme estimated that renewable energy alone could create 20 million jobs worldwide by 2030.

Yet, no matter how much we want and need these jobs, the industries of the future will not belong to America by fiat. Developing nations such as China, India, and Brazil also are determined to take a technology-driven path to prosperity. Research and development expenditures worldwide doubled between 1996 and 2007. Developing countries are investing substantially in higher education in science and engineering, in order to create a culture of innovation—and a workforce ready for the industries of the future, while the United States (in a recent Information Technology and Innovation Foundation study¹) is ranked last of forty countries on metrics of “rate of change

¹ 2009 Information Technology and Innovation Foundation Study in Democracy Journal
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in innovation capacity”, i.e., in human capital development, information technology infrastructure, and economic performance.

Fortunately, technological progress is not a zero sum game. A world that devotes more of its resources to research and education can only be a better world. However, it also is a world where the products of yesterday—and the jobs attached to them—are commoditized, instantly, around the globe. Continuous innovation is now demanded of us, if we hope to retain our high standard of living.

Yet, in recent years, the United States has suffered a loss of focus when it comes to innovation. We do not always capitalize on our opportunities. For example, because we did not put incentives in place over the last decade to create a vigorous market for clean energy, the majority of leading solar panel and wind turbine companies now are located outside the United States.

Both business and government have become somewhat cautious in supporting research projects, preferring less risky short-term projects, rather than the long-term, high-risk basic research that yields the most transformative innovations.

We no longer export as much as we should. Over the last decade, as the assembly of computers and their components has moved to Asia, our trade surplus, even in high-technology goods, has turned into a substantial deficit.

Possibly most worrisome of all for our future is a looming gap between our economy’s need for scientists, mathematicians,

engineers, and technologically skilled professionals—and our success in producing them.

To meet these challenges, we must turn, once again, to that historically powerful partnership of industry, government, and universities. This partnership remains vital, but there are weaknesses at the intersections of the three sectors that must be addressed. We need to turn our innovation economy into an innovation ecosystem—one that offers groundbreaking ideas, and appropriate multi-sector support at every step on the road from scientific discovery to new industry.

History and the lifecycles of technologies suggest that four elements are necessary for such an ecosystem:

- First, strategic focus;
- Second, transformative ideas;
- Third, translational pathways that bring those ideas into the marketplace;
- And fourth, the capital to make the system run: financial, human, and infrastructural capital – that includes advanced manufacturing capacity.

Let us begin with strategic focus.

President John F. Kennedy's 1961 charge to the country to put a man on the moon before the end of the decade offers us an example of the startling power of a strategic grand challenge. By setting such a

goal, he unleashed a flood of investments in science and education, and ignited a new spirit of discovery that not only benefitted the scientists of my generation, but the United States economy as a whole.

The younger members of today's audience might dismiss such bold leadership as a folk tale from a simpler time. However, it is important to remember that the glories of the Apollo era grew out of the fear that America was falling behind as a scientific and technological power. We were worried about being eclipsed by the Soviet Union. Today, we fear being eclipsed by China.

It is clear that, as a society, we face two great challenges that demand transformational technologies: first, energy and environmental sustainability, and, second, more effective, evidence-based medicine, and a more efficient, inclusive health care system.

It is instructive to consider what is required to create a sustainable energy system. We obviously need an overall national energy strategy. A suggested strategy and action plan were laid out by the U.S. Council on Competitiveness in its Energy Security, Innovation, and Sustainability initiative, which 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. Third, if the future of transportation is to be more 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 themselves 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 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.

However, before there can be new industries, there must be transformative ideas, the key element in an innovation ecosystem. Game-changing ideas tend to arise out of basic research, which pushes the boundaries of human knowledge. As well, the endpoints of research in terms of eventual use often cannot be envisaged — even by the researchers themselves. History is replete with startling juxtapositions of initial purpose and eventual application — such as microwave technologies developed for missile detection which, now, are used in cancer treatments.

History also shows that out of open, long-term, sometimes directed, 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 (itself spawning myriad enterprises).

Other examples include DARPA support for VLSI chip development, DoD and NASA for composite materials, NSF for supercomputers and NSFNet, and DoD for the GPS system.

Unfortunately, in recent years, across multiple sectors, we have stunted 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.

As a consequence, universities increasingly are the locus of basic research, which unites seamlessly with our mission to educate. However, government agencies, in supporting university research,

have focused, increasingly, on safe, near-term bets, preferring to fund incremental projects proposed by researchers.

Since business and government benefit from basic research done in universities, they should support it in a robust, consistent, and more patient way.

Next, we must improve the translational pathways that bring ideas into applied, commercial, and societal use. One pathway involves the protection, regulation, and exploitation of intellectual property. There always have been university discoveries that have been commercialized. The Bayh-Dole Act sought to spur this further by giving universities ownership of the results of their federally funded research, the right to patent and license these results, 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. Because of their educational mission, and because there are costs in converting the work done at universities into private property, universities must adopt a sensible approach to the intellectual property that emerges from their laboratories. They must balance the virtues of commercializing new discoveries, with the free sharing of key ideas to allow further discovery and innovation, while also taking account of the ethical and security issues inherent in technologies that can be used for good or for ill.

Within such a 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 research. Data must be, and are, shared openly, for easy collaborations among researchers. To that end, 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.

But commercial enterprises do, and should, spring from university research results. We need to support the fledgling start-ups that grow out of university research, and those independently created by entrepreneurs, and network them into the innovation ecosystem. At Rensselaer, we created one of the first university-based business incubators in the country, to help start-ups bring their products to market. Today, the standardized services incubators offer — accounting, legal advice, a fax machine and desk — while necessary, may not be adequate to launch breakthrough enterprises in fields such as synthetic biology or nanomaterials. Today, we are in the process of refocusing our efforts on targeted innovation in key areas, with new models for incubation and commercialization, tied to regional economic development.

The fourth element required by our innovation ecosystem is capital: financial, infrastructural, and human.

Financial capital clearly is a challenge in the current economic climate, particularly for new technologies requiring seed or early-stage investments. 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 broad use technological breakthroughs that offer them no exclusive competitive advantage.

We very well may need more early-stage government support for potentially transformative technologies that cannot find industry backing.

Infrastructural capital is equally crucial for new enterprises or smaller, evolving, ones. It may include research facilities, as well as computational capability, instrumentation, robotics, clean rooms, and materials fabrication and process facilities — that no single start-up company can afford. Some universities have such critical infrastructure – for research and education, but they cannot become simply an early-stage platform for business, since this may compromise both their mission to educate and their tax status. Other models are needed.

What are some alternatives? Shared infrastructure could be developed in certain sectors by industry consortia. It could be created

at universities or federal laboratories in arms-length entities, with infrastructure specifically shared with nascent industries. An example is provided by the Rensselaer Computational Center for Nanotechnology Innovations (CCNI). A joint project of IBM, New York State, and Rensselaer, it not only hosts one of the world's most powerful university-based supercomputers, it allows companies of all sizes to perform research, simulations, and modeling, and to tap the expertise of Rensselaer scientists and engineers who would otherwise be inaccessible. Yet, the CCNI provides immense computational power for Rensselaer faculty use in basic research. In the words of Gary Pisano and Willy Shih of Harvard Business School, an infrastructural “commons”, co-located with the intellectual “commons” of the university, is a powerful attractor.

This is all well and good, but what about manufacturing itself?

A recent piece in the *Harvard Business Review* by Professors Pisano and Shih suggests that, in high-tech industries, new product development often grows out of process development for other products. By outsourcing the manufacture of semiconductors to Asia, for example, we have lost our capacity in thin-film coating, which has limited the ability of our solar panel industry to create the most advanced products.

Our ecosystem will be far healthier if we make it advantageous for manufacturers to build leading-edge products in the United States. A change will require reassessment and revisions to tax policy and

other financial incentives, and possible regulatory policy change at the Federal and State levels. Many business, government, think-tank, and academic groups are working through these and other policy issues. But let me stick to the bailiwick I know. We need to revitalize the manufacturing economy of the United States, and emerging technologies offer an important opportunity.

From a technological point of view, the future of manufacturing lies in robotics, advanced materials, sensors, biotechnology, and information technology. We must decide to lead in these fields. More broadly, we can build upon the type of road-mapping exercise undertaken by the National Science Board in robotics — to identify important cutting-edge technologies, and new processes, relevant across multiple fields, that show the most promise for evolving manufacturing in key fields, such as health care and energy; and to lay out the facilitating framework for deploying such technologies in the United States.

However, even the most advanced factory is meaningless if our ecosystem does not produce a workforce capable of staffing and running it. An innovation ecosystem must have human capital. Currently, given our large pool of unemployed workers, nearly every job opening attracts numerous applicants. Nonetheless, manufacturers cite an inability to find the right talent as one of their greatest concerns.

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. Possibilities include making worker training benefits portable, and giving private industry a stake in creating a pipeline of workers through appropriate tax incentives.

The United States is not educating enough scientifically literate people in general, technically skilled workers, and scientists and engineers in particular. While job growth in science and engineering fields has been vigorous, at about 4.2 percent per year since 1980, growth in science and engineering degree production has been comparatively weak, at about 1.5 percent per year, and we are doing a particularly poor job of recruiting to these fields the “under-represented majority” of women and minorities.

We have compensated for that gap by attracting foreign scientists and engineers, and we must do everything possible to ensure that we continue to attract and retain the best and the brightest from around the world.

At the same time, we are failing, clearly, to inspire many American children with the wonders of the natural world, mathematics, materials, and machines.

I call this convergence of trends the Quiet Crisis – quiet because it can take a generation to manifest itself fully in our economy, and

because it takes decades to educate a world-class scientist or engineer. It is a crisis, if there is a shortfall, because of the pivotal role of scientists, engineers, innovators, and entrepreneurs in our economy.

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, to ground them in fundamentals, — and to lead to advanced study those who will sustain our innovation ecosystem.

Fortunately, all three partners in our innovation ecosystem understand the economic implications of STEM education, and are working vigorously to improve it. Ohio, with its STEM Learning Network, has been a leader in partnering with industry for this effort. We also need innovation in pedagogy – in how we teach our students. We need to reach them where they are, take advantage of their natural exposure to technology (e.g., social networking), use virtual immersive environments, even games to teach in new ways.

At Rensselaer, for two years – supported by the Gates Foundation – we had the privilege of hosting and working with teachers from Cleveland's two superb STEM schools—the MC² STEM High School and the Design Lab Early College High School— in summer programs, designed to share the insights we have developed in teaching undergraduates in a technological studio

context and multidisciplinary “capstone project” model. If we intend to improve STEM education, we must welcome K-to-12 teachers into the community of scientists and engineers—to offer them both an opportunity for continuous learning, and the respect they deserve.

Ultimately, however, we will not reach a turning point in STEM education until we change our culture – to celebrate the achievements of scientists, engineers, and innovators of all kinds, and those who teach them—while at the same time helping all of our children to imagine themselves in such roles. This is a task that cannot be left to teachers alone.

In the 1920’s, President Calvin Coolidge famously asserted, “The chief business of the American people is business.” Today the chief business of the American people must focus on scientific discovery and technological innovation, and the development of the talent to make them happen. It must be the chief business of children, parents, job seekers, titans of industry, artists, video-game designers, educators, and elected officials. It is up to all of us to make this necessity more widely understood.

It is time for us to see that within our current challenges—within our lost jobs and foreclosed homes, our concerns about energy security and climate change, and health care – lie expansive economic opportunities. We need to confront our challenges with focus, courage, and all of the scientific and technological ingenuity we can muster. We need to rebuild our innovation ecosystem.

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.

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