To:
President Barack Obama
The White House
1600 Pennsylvania Avenue NW
Washington, DC 20500

Dr. John P. Holdren
Director, Office of Science and Technology Policy
Executive Office of the President
725 17th Street NW, Room 5228
Washington, DC 20502

Submitted Through: challenge@ostp.gov

From:
Susan Hockfield
President, Massachusetts Institute of Technology

Date: April 15, 2010

Subject: Recommendations Concerning Grand Challenges of the 21st Century; Request for Information (http://www.ostp.gov)

Dear President Obama and Dr. Holdren:

I am writing in response to the Office of Science and Technology Policy's February 4, 2010 Request for Information (RFI) on "Grand Challenges." In this submission, I will outline five areas that I believe are particularly ripe for encouragement and investment in order to address President Obama's stated Grand Challenges. These areas include: 1) energy technology; 2) the convergence of the life sciences with the physical sciences and engineering; 3) the merger of robotics, advanced computing, and artificial intelligence; 4) new materials; and 5) advanced manufacturing.

The United States currently faces complex, difficult economic challenges. Twelve million jobs must be created this decade just to keep pace with expected workforce growth and normal job churn, in addition to the eight million jobs lost during this recession. One result of this structural recession, as opposed to a business cycle recession, is that significant sectors in our economy have been damaged, with corresponding lasting cutbacks in areas such as the automotive sector. Most of the lost jobs will not come back, and the U.S will have to develop new sectors to make up the losses. A vital question is how to accomplish this.

In the 1990s, the U.S. emerged from a serious recession by driving a major innovation wave – the Information Technology (IT) revolution. It was transformative: the U.S. economy created a net 22 million jobs in the 1990-2000 decade. During that decade, the country faced tough competition from Japan and Germany, but the IT innovation wave put us economically ahead by the end of the decade. The country followed the IT wave with another, in biotechnology, and our economy became the envy of the world.

The economy grows, as Nobel Economist Robert Solow schooled us, predominantly through "technological and related innovation." Economic history tells us that it takes decades of investment in science and technology to drive a new innovation wave. For example, the U.S. began serious work on computing during and just after the Second World War but computers only appeared on every desktop in the 1990s, and the Internet didn't scale until the mid-1990s. Other evolving technology advances now in our sights could be accelerated by government support and carefully crafted public-private collaboration. With encouragement and support, these technology advances could power the innovation waves that resupply the U.S. jobs pipeline.

The five areas identified above are prime candidates for focused efforts in innovation acceleration. First, there are a host of new advances in *energy technology* within range for demonstration and scale up. Second, the *convergence between the life sciences and the engineering and physical sciences* holds the promise to yield a host of new devices, diagnostics and therapeutics that could extend and strengthen the biotech revolution. Third, technologies developed from advances in the merger of *robotics, artificial intelligence and computing* could bring dramatic efficiencies to a wide range of sectors from agriculture to health care delivery. Fourth, a host of *new materials* under development could be brought to bear on a number of challenges, from the manufacturing sector to clean energy technology. Finally, the U.S. must revitalize its *manufacturing sector* to ensure that the country can maintain the lead in producing the products emerging from these and other advanced technologies. These technology opportunity areas are interrelated and offer significant synergies that could be highly advantageous; they should be pursued in parallel and via mechanisms that allow both for diversity of paths of enquiry but also coordination. For example, advances in energy efficiency, robotics, computation, and materials could be deployed in advanced manufacturing.

These five areas will significantly contribute to meeting the Grand Challenges described in President Obama's *Strategy for American Innovation*. At MIT, we see remarkable developments in these fields almost every month. None of these areas will create a million jobs on day one – each requires accelerated investment, support, and nurturing. With appropriate support, they could start to scale in three to six years. Each of these technologies could help drive a virtuous cycle in our economy, a cycle we have seen many times before, where public research and development (R&D) investment leverages private sector investment, and new technology commercialization leads to economic growth and job creation. We should accelerate this virtuous cycle sooner rather than later.

During the 1980s, MIT gathered together faculty and researchers to analyze the country's economic challenges, and provided advice on innovation policies and the emerging technologies that ushered a the subsequent decade of growth. On March 1, 2010, I hosted a roundtable at MIT seeking ideas from our faculty and researchers on approaches that could contribute to the nation's innovation challenges. During this event, faculty discussants considered emerging sectors that could contribute to the country's economic growth, along the lines described above, and policy approaches that would strengthen the U.S. role in both propelling and prospering from these new innovations. On March 29, 2010 I hosted a follow-on discussion focused on technology advances in manufacturing. Below is an outline of highlights from discussions at both of these roundtables. I have also enclosed summaries of both roundtables. A full video of each event is available at the following website: http://alum.mit.edu/innovation.

In each of the areas discussed below, the recommendations are meant to be preliminary and suggestive, not final. Each area requires a strategy development process to flesh these out, including a thorough review that incorporates public, private and research sector participation. In addition, there is an issue for each field regarding the stage of technology deployment and the most effective mechanisms of commercialization, a particularly difficult policy challenge. You are seeking comments later this month on a separate "Request for information" to explore this problem of technology transfer. Although each innovation sector identified below is different and so will have a different launch trajectory, nonetheless there will be common elements. My colleagues and I at MIT hope to submit ideas for such elements in your subsequent RFI.

1) Energy Technology

The triple challenges of climate change, energy security, and affordable energy require the U.S. to shift as quickly as reasonably possible towards low-carbon energy supplies and more efficient energy use. Innovation will be essential to this shift, as most of the low-carbon energy technologies available today are too expensive or otherwise unable to compete against incumbent fossil fuel technologies. Ultimately, our ability to negotiate the energy transition will hinge on how quickly we can bring on new and affordable low-carbon energy technologies. As noted in recent reports from the Information Technology Innovation Foundation[1] and the Pew Center on Global Climate Change[2], the U.S. is swiftly forfeiting the energy technology advantage to our economic competitors, from China and India to Germany and Japan. Energy technology will likely constitute the next major world-

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[1] *Rising Tigers, Sleeping Giant: Asian Nations Set to Dominate the Clean Energy Race by Out-Investing the United States*, The Information Technology and Innovation Foundation, November 2009 (http://archive.itif.org/index.php?id=315)

[2] *Who's Winning the Clean Energy Race? Growth, Competition and Opportunity in the World's Largest Economies*, Pew Charitable Trust, March 2010 (http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Reports/Global_warming/G-20%20Report.pdf)

wide innovation wave, and present corresponding economic opportunities. It is by no means clear whether the U.S. will provide the leadership for this next wave.

The energy innovation problem encompasses multiple and sometimes conflicting goals.[3] The U.S. must reduce carbon emissions, increase energy security, and push for affordable energy prices while simultaneously developing new industries and jobs that accompany them. Success will only come if the technology is adopted by an enormous number of users – this presents a profound challenge of scale. Cost competiveness will be essential because while users may care about energy services and origin, they care primarily about cost.

Three separate phases of innovation could facilitate the clean energy transition. First, the U.S. could achieve improvements in energy efficiency through prompt implementation of new efficiency technologies — not only via traditional business approaches but also via novel and creative business models. Second, the U.S. could accelerate R&D and deploy at-scale, emerging low carbon energy supply technologies, and drive down their costs through continual advances. Third and finally, the U.S. could draw on entirely new concepts, processes, and materials being pursued by basic and applied researchers, with the recognition that these breakthroughs may not make major contributions until mid-century due to longer timescales for technology development and turnover of energy capital stock. Strengthened R&D related to each of these phases, however, must occur throughout this four decade time period.

These phases of energy innovation must be pursued aggressively together and in coordination; unfortunately, the innovation system of today cannot meet these needs. True energy innovation will require hundreds of billions of dollars a year of mostly private investment in cost competitive, scalable, and environmentally benign new technologies. It will require thousands of new sites to become available for the construction of sometimes controversial energy facilities and infrastructure, and the training every year of tens of thousands of young people from craft workers to Ph.D. scientists and engineers.

The challenge of energy innovation is different from other kinds of innovation because the major impetus for it comes from outside the marketplace. The government must fund R&D on a significantly larger scale, and use price adjustments to stimulate demand for low carbon energy technologies. The U.S. must also overcome three major obstacles to meeting the nation's energy goals. First, a more realistic view of the *scale of the problem* is needed — the innovation challenge is much larger than most people think, and it will require a more comprehensive strategy than anything that has come before. Second, a strategy of the necessary size and scope will not be sustainable without a *durable base of support* similar to that in the defense technology sector, where a combination of a potent external threat,

[3] Lester, Richard, *America's Energy Innovation Problem (and How to Fix It),* November 2009 (http://web.mit.edu/ipc/research/energy/index.html)

substantial opportunities for business and job creation, and a powerful industrial base contributed to public understanding and support. Third, the U.S. must *reinvent its current energy innovation organization and structure*. New strategies and institutions will be necessary, both to support R&D and the crucial downstream activities of demonstration, commercialization, and the early stages of large-scale technology take-up.

Recommendations:[4]

- Ensure that Department of Energy's (DOE) new programs focused on the R&D side of the innovation cycle — Energy Frontier Research Centers, Advanced Research Projects Agency for Energy (ARPA-E), and Energy Innovation Hubs — along with basic clean energy research in the Office of Science receive increased, reliable, long-term funding.

- Provide support and resources to address the back-end (market-pull) of the innovation cycle through large-scale deployment of new technologies and collaboration with other Federal agencies (for example, coordination with the Department of Defense) to act as test beds for implementation of new technologies. Overall interagency coordination will need significant additional attention.

- Expand the DOE loan guarantee program, and explore alternative financing mechanisms. Possible creative financing mechanisms can be found in both the American Clean Energy and Security Act (H.R. 2454) and The 21st Century Energy Technology and Deployment Act (S.949).

- Support educational efforts, such as DOE's proposed Regaining our Energy Science and Engineering Edge (E-ENERGYSE) program, to educate the next generation of energy technology leaders that will play a crucial role in further advances.

- Develop a true energy technology strategy through a coordinated. public-private process.

2) Convergence between the life science, physical sciences, and engineering

The convergence of engineering and physical sciences with life sciences will be a major source of innovation for the coming decades. This convergence could address many of the major challenges facing society today; advancing the quality of healthcare at lower cost, providing new sources of energy for transportation and of materials, increasing the availability of food by increasing productivity of plants, and

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[4] See, generally, MIT President Susan Hockfield's Testimony before the House Select Committee on Energy Independence and Global Warming, September 10, 2008 (http://globalwarming.house.gov/pubs/archives_110?id=0053#main_content)

furthering monitoring and engineering of environmental systems to enhance their protection. These and other benefits are laid out in a report recently issued by the National Academy of Science entitled "*The New Biology for the 21st Century.*"[5]

The applications in health are particularly significant. The newly emerging convergence of life sciences and engineering can be pictured as a "third revolution" that has its origins in two earlier life sciences revolutions.[6] The first revolution occurred in the 1950s and 1960s with the discovery of the structure of DNA and the development of molecular biology that gave rise to biotechnology in the 1970s. During this period, biotech companies such as Genentech, Biogen, and Genzyme were established. Later, international pharmaceutical companies adopted the biotechnology research approach both substantively in terms of scientific tools but also organizationally, forging new and closer links to academia.

Science advanced with a second revolution at the turn of the century — the integration of early advances of computation, bioinformatics, and engineering with molecular biology that allowed the sequencing of the human genome. Through these and other advances, we have begun to elucidate the working parts of cells and to learn how small sets of these parts function in systems in normal and disease processes.

We now stand on the cusp of a third revolution, represented by the convergence of the life, engineering, and physical sciences. Scientists and engineers have begun to move beyond traditional disciplinary silos to realize the remarkable opportunities available when these fields converge. The advances of information technology, materials, imaging, nanotechnology, advanced optics, quantum physics, advanced computing, sensors, modeling, simulation, and probability have transformed physical sciences and engineering, and are now being brought to bear on life sciences. In turn, the fundamentally different but potentially complementary approaches of complex systems in biology are being joined with engineering design. This promises is not only remarkable new knowledge bases, but also new therapies and devices.

As we have seen in the human genome project, interdisciplinary teams need to work together to develop new technologies and computationally address the complexity of data in many areas of research in life sciences. This will only increase as even more powerful high throughput methods are used to explore cellular systems. There remain, however, significant impediments to realization of the innovations promised by convergence that could be initially addressed through the recommendations listed below.

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[5] *A New Biology for the 21st Century*, National Research Council of the National Academies, 2009 (http://www.nap.edu/catalog.php?record_id=12764)

[6] Susan Hockfield, *The Role of the Life Science in Transforming America's Future*," 2008 National Academies' Biology Summit (Dec. 3, 2008) http://web.mit.edu/hockfield/speeches/2008-nrcsummit.html

Recommendations:

- Provide funding for the National Institutes of Health (NIH) and other agencies to support this revolution: Important parts of NIH, such as the National Cancer Institute (NCI), are supporting convergence-based advance, but other NIH Institutes and Centers need to consciously adopt and nurture it as well, to ensure that convergence impacts as wide a range of disease areas as possible. The NIH will need to support more interdisciplinary approaches for this revolution in medical research to flourish and support more diverse funding approaches that allow and encourage participants across disciplines. Similarly, organizations as diverse as the Defense Advanced Research Projects Agency (DARPA), Army Medical Research, the National Science Foundation (NSF), the Office of Science at DOE, and the Department of Agriculture should also develop convergence as an area for program emphasis within their funding streams. A mechanism for interagency collaboration to exploit research opportunities will also be required.

- Encourage discoveries at the interface of the life and physical sciences: As NIH's Roadmap effort and the Congressionally authorized Common Fund (for cross-agency research advances) recognize, the individual divisions of the NIH Institutes and Centers can limit high-risk, interdisciplinary, cross-sector research. The roadmap and the Common Fund, as well as other trans-NIH mechanisms and interdisciplinary efforts at existing Institutes and Centers need to be used and expanded to support the convergence revolution.

- Balance larger-scale efforts with smaller grant projects: Larger-scale projects allow researchers from many disciplines to conduct systematic inquiries into general target areas, while still allowing for individually determined specific projects. New and innovative research emerges as the projects bring potential collaborators together to work on similar problems using a wide range of approaches. However, individual grants are a time-honored and respected tradition in the U.S. research enterprise that provide a critical broad base of advance and allow for high-risk projects to be rapidly implemented in advance of larger grants; they should be complemented with new collaborative, interdisciplinary work. Both programs will also need to be funded in creative ways.

- Enhance the NIH peer-review organization to allow for more effective interdisciplinary evaluations*:* Most federal agencies rely on the well-established and respected peer review model. NIH's ability to undertake cutting edge, higher-risk research could be enhanced by creating interdisciplinary peer review teams that can effectively evaluate cross-disciplinary research proposals as convergence grows. Other U.S. science agencies should follow NIH's efforts in this regard.

- Undertake new efforts to educate the next generation of researchers to work in cross-disciplinary fields: In this time of a flattening world with ever-increasing investments in research by competitor nations, the U.S. science talent pool is a lasting advantage. New programs to enable cross-disciplinary expertise and training will be crucial to training a new generation of research leaders that can lead advances through convergence.

- Consider novel models of technology transfer and proof-of-concept research funding: While convergence offers a wide range of potential solutions to pressing health-related issues, it poses significant challenges for commercialization because new business models must be developed, entrepreneurs educated to understand and mitigate the risks of such approaches and the private sector involved. New programs for directed proof-of-concept research and translational efforts should complement basic research funding.

3) The Merger of Advanced Robotics, Advanced Computing, Artificial Intelligence

Over the last decade, The U.S. has seen the successful marketplace entry of surgical robotics, home cleaning robots, and military robots. The growth is spectacular—more than 10,000 ground robots and thousands of aerial robots in the U.S. military and over five million robots in people's homes, both up from zero in June 2002. Robotics has taken off for three primary reasons. First, computation and sensors have become exponentially cheaper in the last fifty years. Second, research in computer vision and simultaneous localization and mapping has made major strides in the last ten years. Third and finally, for certain tasks, robots have passed the usability threshold that makes them useful to untrained people.

A new generation of robotics, coupled with major advances in computing and artificial intelligence, is now emerging with potential in a series of sectors. In the area of manufacturing robotics, for example, current technology is engineered to be precise and repeatable, not adaptable, and the robots are sometimes unsafe for people to be around. These costly, heavy, and fixed robots can only operate in very structured environments with limited application. Advanced robotics could influence a new vision for American manufacturing that includes skilled workers using robots to produce both high-value and mass-market products. Robots could empower workers by taking over simple tasks and giving them new tools to manage complex tasks. This could break the relentless repetitive routine of the assembly process and free workers to work smarter and manage a range of increasingly sophisticated tasks. This same approach could apply to such areas as agriculture, mining, health care services and transportation.

In addition to robotics, computation has deeply affected the global economy. The earliest computers were invented to compute trajectories; mainframe computers sped up billing and insurance; desktop computers increased personal productivity; and, more recently, networked computers with sensors enable real-time monitoring and surveillance applications. This trend is moving toward more interactions in the physical world, merged with robotics, which can act in the world through and for us. Ordinary objects among us will start to become programmable so that we can adjust their properties to enable functionality. There is a significant case to be made for a new level of innovation across a series of sectors that will occur through the merger of computation, robotics, artificial intelligence, and related disciplines.

For example, computation and biology will transform each other. Computation has already caused breakthroughs in biology, like genome sequencing and behavior modeling. In turn, biology is transforming computation and providing new complex system challenges that force computer scientists to revisit how they represent data and computation, and organize their priorities. Some goals for representation include experimental design, predictive modeling, automated reasoning, and query processing. Some examples of biology transforming computation include personalized medicine, drug design, and the understanding of evolution. The combination of robotics tied to IT systems in symbiosis with human operators, with computational advances in the medical area, offers an important merged innovation opportunity.

Recommendations:

- Follow the *Roadmap for U.S. Robotics, From Internet to Robotics.*[7] This document, prepared as a collaborative strategy by universities and industry, could serve as a tool for the executive branch agencies to identify research areas and policies to further innovation in robotics.

- Increase federal funding to support research in cost-effective, resource-efficient manufacturing that could empower workers and benefit consumers.

- Expand and institutionalize initial efforts at OSTP to encourage a series of federal agencies with a major stake in advances in robotics, related computation, and artificial intelligence to create a collaborative effort to share their research efforts and advances for mutual gain and efficiency.

- Consider development of robotics programs focused not simply on high-end high value processes, but also on small and medium sized business, comparable to the European Union's Small/Medium Enterprise Robotics Program.

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[7] *Roadmap for U.S. Robotics, From Internet to Robotics,* Computing Community Consortium*, May 2009 (www.**us-robotics.us**/reports/CCC%20Report.pdf)*

- Undertake efforts to reframe robotics and computing as tools to empower and support, rather than displace, American workers.

- Encourage universities to develop academic curricula and programs and training efforts in robotics, including the creation of robotics labs with graduate and undergraduate students. These training programs will help supply the robotics manufacturing and services sectors with educated workers work, and provide tech transfer support for start-up robotics companies.

4) <u>New Materials</u>

We are at the forefront of materials innovation in a series of potentially very important areas, including bio-inspired materials, nano-technology, and lightweight materials. While there are exciting new materials emerging, a major impediment to materials advances is the time to market. It currently takes approximately 18 years for the average new material discovery to reach commercialization. This is too long to wait for a product or an important solution to major challenges. Advances in new materials are needed in the short term to address many of the nation's innovation challenges.

As one example of possible opportunities in this field, the Materials Genome Project underway at MIT aims to predict the properties of all conceivable materials through computation, and to share that information broadly in the scientific community and industry. This will allow materials to be designed and selected with optimal properties to fit particular needs and tasks. This work is founded on the idea that many promising technologies are limited by the lack of an ideal material. This project is creating a virtual environment for materials design, using basic laws of physics and an automated computing environment to predict material properties. The project now has the possibility of computing the properties of all known inorganic materials, as well as many unknown materials.

Another example of exciting materials research is in the area of biomolecular materials, using advanced bioengineering techniques to explore the interface between inorganic and organic materials for applications to energy, medicine, electronics, nano-mechanics, and the environment. These researchers look at how organisms, such as abalone, have evolved over millions of years to make exquisite nanostructures like shells and glassy diatoms using limited elements. The group builds upon these observations and uses directed evolution to encourages organisms to grow and assemble technologically important materials and devices using elements in the rest of the periodic table.

As another example, a number of university laboratories are working on materials systems. At MIT, researchers are doing groundbreaking work on developing lightweight materials for the automotive industry. Lightweight materials in transport vehicles could dramatically transform the sector by allowing for a series of tradeoffs for other technologies, such as increases in vehicle range and fuel efficiency, and significantly greater performance from batteries. While vehicle lightweighting on a large scale would require a redesign of the supply chain and manufacturing capabilities, the resulting product would be a cutting edge, exportable technology that, once formed, would not easily be transferable. This could offer the U.S. a lasting competitive advantage in the automotive sector. Lightweighting, of course, not only affects transport efficiency and performance, but could potentially affect a wide range of sectors.

Recommendations:

- Support programs at federal R&D agencies to increase not only basic research in new materials, but also the testing, demonstration, and commercialization of these new materials to decrease time to market.

- Support efforts such as the Materials Genome Project to speed up design and use of new, advanced materials and encourage widespread dissemination of results to scientists and industry.

- Facilitate research in lightweighting in the transport sector, including its corollary effects related to battery technology and fuel economy. Similar efforts should be attempted in other sectors where lightweighting could lead to significant efficiencies.

5) Advanced Manufacturing

An operating assumption of growth economics is that a nation that initiates innovation will manufacture the products of that innovation, at least until the technology matures, in order to secure the corresponding economic gains. Although U.S. manufacturing output remains the largest in the world, the U.S. manufacturing sector is in decline. The U.S. trade deficit in manufactured products was $500 billion in 2007, and the U.S. even ran a $50 billion deficit in advanced technology goods. Our trade deficit in products has been increasing more rapidly than our trade surplus in services, and now services, too, face increase global competition as a result of IT advances. And it is not the manufacturing assembly moment that will be the job creator. A much greater number of jobs will be directly or indirectly dependent on that product production.

If the U.S. wants to think about reinvigorating this sector, it will have to choose where it can compete. The U.S. likely cannot compete on low value commodity manufacturing, but will rather need to found a new kind of 21st century manufacturing driven by innovation. Experiences in Germany and Japan have shown that high wage, high value economies can compete in manufacturing with low wage, low value economies; both nations run major trade surpluses in manufactured goods. There are a series of areas in manufacturing that I believe constitute new paradigms for a new kind of manufacturing, including nano-manufacturing; "network-centric" manufacturing; low-volume, low-cost manufacturing; sustainable manufacturing; and the application of advanced materials. Aspects of some of these advances have been described above, in the robotics/computing, new materials, and energy efficiency sections.

As one example, research is underway in many fields of nanotechnology related to manufacturing, supported by the long-standing and critical federal R&D initiative in nanotechnology. One example of exciting nano-manufacturing work is at MIT's Precision Compliant Systems Lab. This lab focuses on new, small-scale manufacturing, and on training the next generation of nano-manufacturing professionals. This lab generates the knowledge required to engineer nano-, micro- and macro-scale compliant mechanical systems to ultimately increase the type and pace of scientific discoveries through instrumentation, and the pace and quality with which these discoveries may be converted into tangible goods through manufacturing. Nano-manufacturing equipment requires devices that may only obtain viable speed, cost, and stability requirements if they are tens of nanometers in size. Two critically important keys to success in nano-manufacturing include integrating science into the manufacturing process and developing a critical mass of talent with expertise in this area.

Important work is also underway in the other paradigms listed above, elements of which were summarized in a roundtable at MIT on manufacturing on March 29, 2010 during which, as noted at the outset of this document, a number of faculty discussants considered technology advances that could benefit manufacturing. Below are several preliminary recommendations to encourage an advanced U.S. manufacturing sector. I also encourage your attention to ongoing manufacturing studies being conducted by President's Council of Advisors on Science and Technology (PCAST) and the Council on Competitiveness.

Recommendations:

- Encourage the private and public sectors to embrace advanced manufacturing as a critical feature in the nation's long-term economic growth.

- Increase funding for manufacturing R&D, focused in the following five potential new paradigm areas: new materials; nano-manufacturing; low volume, low cost manufacturing; network-centric manufacturing; and sustainable manufacturing. In addition to research in emerging technologies in these areas, studies in related processes and businesses models must also be undertaken.

- Encourage collaboration between existing government manufacturing programs, for example at the Manufacturing Engineering Laboratory and the Manufacturing Extension Program at the National Institute of Standards and

Technology (NIST), the Department of Defense's Mantech program, and manufacturing R&D programs at DOE and DARPA. A coordinated interagency program that includes R&D, demonstration and testbeds, in collaboration with the private sector, will be critical.

- Increase support for training and workforce for the next generation of manufacturing professionals.

In closing, I want to express MIT's appreciation for the President's efforts to harness science and technology to address the Grand Challenges of the 21st century. I hope you find this submission useful in identifying possible directions to serve this end. The MIT faculty and researchers stand ready to assist you as you implement this strategy. If your offices have questions related to follow-up, please contact William B. Bonvillian in our Washington, DC Office at (202) 789-1828.

Sincerely,

Susan Hockfield

Enclosure:

1) Summary of March 1, 2010 Innovation Roundtable
2) Summary of March 29, 2010 Innovation in Manufacturing Roundtable
3) Link to innovation roundtable discussions at MIT: http://alum.mit.edu/innovation