ASSESSING CHINA'S EFFORTS TO BECOME AN "INNOVATION SOCIETY" – A PROGRESS REPORT

HEARING

BEFORE THE

U.S.-CHINA ECONOMIC AND SECURITY

REVIEW COMMISSION

ONE HUNDRED TWELFTH CONGRESS

SECOND SESSION

MAY 10, 2012

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UNITED STATES-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

WASHINGTON: 2012

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The Commission was created on October 30, 2000 by the Floyd D. Spence National Defense Authorization Act for 2001 § 1238, Public Law No. 106-398, 114 STAT. 1654A-334 (2000) (codified at 22 U.S.C. § 7002 (2001), as amended by the Treasury and General Government Appropriations Act for 2002 § 645 (regarding employment status of staff) & § 648 (regarding changing annual report due date from March to June), Public Law No. 107-67, 115 STAT. 514 (Nov. 12, 2001); as amended by Division P of the "Consolidated Appropriations Resolution, 2003," Pub L. No. 108-7 (Feb. 20, 2003) (regarding Commission name change, terms of Commissioners, and responsibilities of the Commission); as amended by Public Law No. 109-108 (H.R. 2862) (Nov. 22, 2005) (regarding responsibilities of Commission and applicability of FACA); as amended by Division J of the "Consolidated Appropriations Act, 2008," Public Law Nol. 110-161 (December 26, 2007) (regarding responsibilities of the Commission, and changing the Annual Report due date from June to December).

The Commission's full charter is available at www.uscc.gov.

June 4, 2012

The Honorable Daniel Inouye
President Pro Tempore of the Senate, Washington, D.C. 20510
The Honorable John A. Boehner
Speaker of the House of Representatives, Washington, D.C. 20515

DEAR SENATOR INOUYE AND SPEAKER BOEHNER:

We are pleased to notify you of the Commission's May 10, 2012 public hearing on "*Assessing China's Efforts to Become an Innovation Society-A Progress Report*." The Floyd D. Spence National Defense Authorization Act (amended by Pub. L. No. 109-108, section 635(a)) provides the basis for this hearing.

At the hearing, the Commissioners received testimony from the following witnesses: Dr. Robert D. Atkinson, President, Information Technology and Innovation Foundation; Dr. Danny Breznitz, Associate Professor of International Affairs, Georgia Institute of Technology; Richard P. Suttmeier, Professor of Political Science Emeritus, University of Oregon; Dr. Denis Fred Simon, Vice Provost for International Strategic Initiatives, Arizona State University; Dr. Earl C. Joseph II, Program Vice President, IDC; Dr. Horst Simon, Deputy Director, Lawrence Berkeley National Laboratory; Timothy K. Harder Director, EMC Cloud Infrastructure Division; Kathleen Walsh, Associate Professor of National Security Affairs, U.S. Naval War College; and Dr. Thomas Mahnken, Professor of Strategy, U.S. Naval War College. The hearing provided a broad overview of the innovation climate in China and specifically addressed research and development programs, emerging information and communication technology capabilities, and Chinese defense sector innovation. The hearing reviewed these issues in the context of their implications for the United States.

We note that prepared statements for the hearing, the hearing transcript, and supporting documents submitted by the witnesses will soon be available on the Commission's website at www.uscc.gov. Members and the staff of the Commission are available to provide more detailed briefings. We hope these materials will be helpful to the Congress as it continues its assessment of U.S.-China relations and their impact on U.S. security.

The Commission will examine in greater depth these issues, and the other issues enumerated in its statutory mandate, in its 2012 Annual Report that will be submitted to Congress in November 2012. Should you have any questions regarding this hearing or any other issue related to China, please do not hesitate to have your staff contact our Congressional Liaison, Jonathan Weston, at (202) 624-1487 or via email at jweston@uscc.gov.

Sincerely yours,

Hon. Dennis C. Shea
Chairman

Hon. William A. Reinsch
Vice Chairman

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ASSESSING CHINA'S EFFORTS TO BECOME AN "INNOVATION SOCIETY" – A PROGRESS REPORT

THURSDAY, MAY 10, 2012

U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

Washington, D.C.

The Commission met in Room 562 Dirksen Senate Office Building, Washington, D.C. at 9:00 a.m., Chairman Dennis C. Shea and Commissioner Carte Goodwin (Hearing Co-Chairs), presiding.

OPENING STATEMENT OF COMMISSIONER DENNIS SHEA HEARING CO-CHAIR

CHAIRMAN SHEA: Good morning. It's 9:00 o'clock. If we could ask the first two witnesses to come forward and give their opening remarks. Good morning, and welcome to the fifth hearing of the U.S.-China Economic and Security Review Commission's 2012 Annual Report cycle.

My name is Dennis Shea, and I am co-chair of today's hearing. We will be examining China's efforts to foster innovation through a variety of policies, some of which are likely to have a profound effect on the United States' economy.

China has made no secret of its ambition to shift its economy from one dependent on manufacturing products invented elsewhere to a more integrated economy that can invent, develop, and produce works whose intellectual property originated within China. The 15-year Medium and Long-Term Plan, adopted in 2006, describes 402 technologies in which China seeks to gain expertise.

The plan also calls for China to limit its dependence on foreign technology to just 30 percent by 2020.

The 12th Five-Year Plan, adopted last year, identifies seven strategic emerging industries in which Chinese corporations are expected to become global champions. They include clean energy technology, next generation information technology, biotechnology, high-end equipment manufacturing, alternative energy, new materials, and clean energy vehicles.

The goal is to triple the contribution that these industries make to Chinese GDP from five percent to 15 percent by the year 2020.

To do this, the Chinese government intends to increase spending on research and development, from 1.75 percent of GDP in 2010 to 2.2 percent in 2015. By contrast, the United States spent 2.9 percent of its GDP on research and development in 2009, slightly higher than the developed country average of 2.4 percent according to the OECD.

Total expenditures by the Chinese central and local government and private sector are expected to total $2.16 trillion over five years, according to the 12th Five-

Year Plan.

China hopes to accomplish its goals through some traditional government policies, such as expanding education in science and technology and increasing basic research through government support. Those methods are certainly consistent with international norms, and China's aspirations to become a technological power are understandable.

But China's intention to follow shortcuts is not acceptable when it conflicts with long-accepted international rules. Issues such as forced technology transfers, the promotion of exclusionary domestic technology standards, and extensive cyber espionage directed at key U.S. industries and technologies continue to complicate the U.S.-China relationship.

Today, we shall also hear about China's self-imposed barriers to becoming an innovation society. Despite years of promises and many volumes of laws and regulations, issued to protect intellectual property from piracy, China has not followed through with anything approaching adequate enforcement. Until China provides protection, for example, for business software from rampant piracy, it cannot expect its own software industry to thrive.

Experts on the first and second panels will testify this morning. We will adjourn for a lunch break at 12:00 noon, after which the hearing will resume in this room at 12:50 p.m., for the remaining two panels.

Before I turn the floor over to my co-chair for this hearing, Commissioner Carte Goodwin, I would like to thank Senator Ben Nelson and his staff for securing this hearing room for us today.

Senator Goodwin.

U.S.-China Economic and Security Review Commission

Hearing on Assessing China's Efforts to Become an Innovation Society—
A Progress Report
Opening Statement of Commissioner Dennis Shea
May 10, 2012
Washington, DC

Good morning, and welcome to the fifth hearing of the U.S.-China Economic and Security Review Commission's 2012 Annual Report cycle. My name is Dennis Shea and I am a co-chair of today's hearing. We will be examining China's efforts to foster innovation through a variety of policies, some of which are likely to have a profound effect on the economy of the United States.

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OPENING STATEMENT OF COMMISSIONER CARTE GOODWIN
HEARING CO-CHAIR

HEARING CO-CHAIR GOODWIN: Thank you, Mr. Chairman.

Good morning. I would also like to extend my thanks to our witnesses for their willingness to share their research and insight with the Commission today. And I've also been asked to point out that this hearing is being webcast, and a transcript will be posted on our Web site at www.uscc.gov.

As the Chairman alluded, China and the United States have taken vastly different approaches to developing a capacity for innovation. China primarily relies on central government planning which is passed down to provinces and ultimately to China's large state-owned and controlled enterprises. The major actors include government-funded institutions, such as the Chinese Academy of Sciences.

By contrast, the United States has traditionally relied on the efforts of individual entrepreneurs, scientists, engineers and inventors, frequently supplemented by government funding, especially for basic research.

Indeed, the history of American innovation has been collectively written as collaboration between government and private industry. Many of the technologies that we take for granted today, including radio broadcasts, naval and aircraft radar, and GPS technology, began as government creations that have been fostered and expanded through work with private enterprise.

Today, we'll be looking at areas where the Chinese government has been a direct participant in innovation, including: supercomputing, cloud computing, and weapon systems. In the case of supercomputers, which have both commercial and military applications, we will see that the U.S. is still dominant in quantity, while the Chinese are building faster machines, often using Western components combined with indigenous Chinese software.

China has also recognized the value of cloud computing, and government programs to advance this important technology are being adopted by state-owned and controlled enterprises.

In the area of weapon systems, much of China's innovation is incremental and duplicative of Western technology. But as we will hear later today, China's anti-ship ballistic missile program, currently in development, represents a potentially radical and game-changing advance in naval weaponry and strategy.

U.S.-China Economic and Security Review Commission

Hearing on Assessing China's Efforts to Become an Innovation Society—
A Progress Report
Opening Statement of Commissioner Carte Goodwin
May 10, 2012
Washington, DC

Good morning. I'd like to thank our witnesses for their willingness to share their research and their expertise with the Commission. And I'd like to point out that this hearing is being webcast and a transcript will eventually be posted on our website, uscc.gov. The written testimony being submitted for the record is also being posted on our website this morning.

China and the United States have taken different approaches to developing a capacity for innovation. China relies on central government planning, passed down to the provinces and to China's large state-owned and state-controlled enterprises. The major actors are government-funded institutions, such as the Chinese Academy of Sciences.

The United States has traditionally relied more on the efforts of individual scientists, engineers, inventors, and entrepreneurs, supplemented by government funding, particularly for basic research. When the United States created a government program, such as our manned space flight program, it drew heavily on the work of publicly owned corporations. The history of American innovation was written as collaboration between government and private industry. Some technologies we take for granted today—radio broadcasts, naval and aircraft radar, the global positioning system or GPS, the interstate highway system--were government creations. But those government creations have today been melded with private enterprise.

We will be looking at some areas where the Chinese government has been a direct participant: supercomputers, cloud computing, and weapons systems. In the case of supercomputers, which have both commercial and military applications, we will see that the United States is still dominate in quantity while the Chinese have built the faster machines, using western microprocessors and indigenous Chinese software. China has recognized the value of cloud computing and its government programs to advance this technology are being adopted by state-owned and controlled corporations. In the area of weapons systems, much of China's innovation is incremental and duplicative of Western technology. But China's

anti-ship ballistic missile program, in development, represents a potentially radical and game-changing advance in naval weaponry and strategy.

We'll now hear from our first panel, which will provide an overview of China's approach to fostering innovation. As a reminder to all the panelists, please limit your opening statement to seven minutes. This will allow plenty of time for questions and answers.

###

PANEL I: CHINA AND INNOVATION

HEARING CO-CHAIR GOODWIN: We will now hear from our first panel, which is intended to provide a broad overview of the progress and prospects for Chinese innovation, and we're pleased to welcome today two witnesses who have studied these issues in great detail.

Mr. Robert Atkinson is President of the Information Technology and Innovation Foundation and the author of the forthcoming book *The Race for Global Innovation Advantage and Why the U.S. is Falling Behind*.

And Dr. Danny Breznitz, Associate Professor of International Affairs and Management at Georgia Tech, has also written extensively on Chinese innovation. His most recent book is *Run of the Red Queen: Government, Innovation, and Globalization and Economic Growth in China*.

Gentlemen, we look forward to your statements. Mr. Atkinson.

STATEMENT OF ROBERT D. ATKINSON
PRESIDENT, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

DR. ATKINSON: Thank you very much. It's a pleasure and honor to be here before you today.

I just want to give a little bit of background. I have, along with Denis Simon here, been advising the Office of Science and Technology Policy on their joint U.S.-China Innovation Dialogue. Denis and I were actually both over in Beijing last week so I've been in that capacity looking at Chinese innovation policy for about 18 months. In addition, in my official ITIF hat, we've been doing a lot of work on Chinese innovation policy, including a recent report called "Enough is Enough: Confronting Chinese Innovation Mercantilism."

And I think we heard already some of the plans for China, but I think one of the key points to understand, at least in our view, is why it's difficult for a lot of American policymakers , pundits and experts to really grasp what China is doing, is because they fundamentally think China thinks about trade the way we do, which is essentially a kind of Ricardian view around comparative or competitive advantage: we're good at something, and somebody else is good at something, and then we trade.

I actually would argue the Chinese are practicing what would be called "absolute advantage." They want to be good at everything, and they have a conscious strategy to do that.

I think one of the easiest places to see that besides the overall MLP or the overall 12th Five-Year Plan is what they're doing in aviation, where they have a goal of, essentially, I would argue, displacing Boeing and Airbus as the global aviation leaders.

COMAC, their big Chinese state-owned aviation company, has said, quote: "We will commit to national and international cooperation based on the airframe suppliers model to share risks and benefits and build a system of both national and international suppliers for trunk lines"--and then the real key part here--"and eventually establish relatively complete service and industrial chains in the commercial airplane business."

Now, there is really no--if you were not massively subsidizing this--there is simply no way a third major airplane company can emerge in the global market because it has such high barriers of entry, enormous capital costs, and not a great big market. So you're never going to get more than Airbus and Boeing. China doesn't like that, and therefore they are working as hard as possible to get in that market.

So rather than go and talk about what the Chinese are doing--because they are doing a lot, as we heard--they're increasing their R&D; they're increasing their number of engineers; they're engaged in a wide variety of what we would call "bad" or mercantilist innovation policies, such as discriminatory technology standards, forced tech transfer, IP theft, and the like--I want to focus on why it is that we have sort of dismissed this threat.

There's a view that we simply shouldn't really worry about China because they're this backward country, that the best they could do is assemble iPhones. They can never invent an iPhone. And I think there are two components to that. One is there is this deeply-held view that the United States is an exceptional country, we've always led in innovation, and we will always continue to lead in innovation. We have Yankee ingenuity; the Chinese don't.

And the second part of this is that our model is the superior model, that really only the Washington model--which is essentially based on free markets, open trade, rule of law, strong IP protection, et cetera--only that model can produce innovation.

And I think there are a couple of things wrong with that view. The first is that that's really about this notion of a particular kind of innovation, which is first-to-the-world innovation, and I would assert that the Chinese aren't very good at first-to-the-world innovation. They didn't invent the iPhone. They don't invent a lot of new, brand new things. We do. And some other countries do too.

And so they are not very good at that, but I think a couple of things. One is they understand that they're not very good at that, and they're working on that. They have some structural problems, including just the lack of a free and democratic economy, and the dominance of SOEs, which squeeze out entrepreneurial companies, but they are trying to work on that.

But I think there is a second component of innovation, which is equally, if not more important, and that's what you would call "innovation adaptation," taking something and then adding to it. That's really how the Japanese moved from a country that made sort of not very good toys in the 1940s and '50s to a world-leading country now.

They were essentially an innovation adapter. They took existing innovations like the sort of historic one of the VCR. We invented the VCR; they perfected the VCR and drove down costs. That's the Chinese model now, and we see that, for example, in the massive effort they're putting in engineering. So we're really great in the U.S. at science-based innovation, but the Chinese are really focusing on engineering-based innovation.

For example, 30 percent of first-time degrees in Chinese bachelors are in engineering compared to just four percent in the United States.

So just to close, let me suggest that I think even if the Chinese don't become strong first-to-the-world-innovation leaders over the next decade or two, they can still become an innovation leader if they put massive efforts into getting FDI attraction from foreign companies, and we've seen that with the massive expansion of R&D in China.

U.S. companies have expanded their R&D overseas 270 percent more over the last decade than they've expanded their R&D domestically. Not all of that obviously is in China, but a lot of it is in China, so even if Chinese companies don't innovate themselves, the threat to the U.S. economy is very real if they continue their policies to incent, induce and force U.S. companies to produce innovation-based products and activities overseas.

The second, as I alluded to earlier, is if the Chinese don't do first-to-the-world innovations, they are fast followers, and they can do a lot of damage to our economy if they can take these innovations, perfect them, and get into the marketplace around them.

And the third is, even if the Chinese fail at that, so they don't even do that well, I would assert that they can still do significant harm to the U.S. innovation economy through their innovation mercantilist policies.

So their IP theft, their standards manipulation, all of these policies, even if they don't really drive a big Chinese innovation economy, they can do damage to U.S.

firms and U.S. jobs within that.

So, thank you.

PREPARED STATEMENT OF ROBERT D. ATKINSON
PRESIDENT, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

May 10, 2012

Dr. Robert D. Atkinson

President

Information Technology and Innovation Foundation

Testimony before the

U.S.-China Economic and Security Review Commission

Assessing China's Efforts to Become an Innovation Society

A Progress Report

For many observers, while China may become a preferred global location for low value-added, commodity-based production, the United States' lead in high value-added, innovation-based production is secure. In this framing, China's emergence has led to the expansion of the global market allowing the U.S. and China to each specialize in their natural area of comparative advantage: China in commodity-based production and the United States in innovation. China, with its state-directed economy, weak intellectual property (IP) protection and limited entrepreneurship is best suited to assemble our I-Phones. America, with our superior entrepreneurial capabilities, design and market them.

While this view may have once accurately characterized both economies, it no longer does. Until the mid-2000s China actively encouraged foreign direct investment in assembly production through a vast array of incentives, many of them mercantilist in nature. But in 2006 that began to change. Chinese leaders decided that attracting commodity-based production facilities from multi-national corporations was no longer the principal goal. The path to prosperity and autonomy was now to be "indigenous innovation" (or in Chinese, zizhu chuagnxin) with Chinese firms the focus.[1] The seminal document advocating this shift was "*The Guidelines for the Implementation of the National Medium- and Long-term Program for Science and Technology Development (2006-2020)*." The so-called "MLP" sought to "create an environment for encouraging innovation independently, promote enterprises to become the main body of making technological innovation and strive to build an innovative-type country."[2] This was much more than a strategy to target some key areas where China had some preexisting capabilities. Rather, the MLP "must be made a national strategy that is implemented in all sectors, industries, and regions so as to drastically enhance the nation's competitiveness."[3] The MLP called on China to "master core technologies" in virtually every area Chinese state planners could imagine. Included were some 402 technologies, from intelligent automobiles to integrated circuits to high performance computers. Five years later it had met at least one its goals. For in 2011 China's announced that it had built the world's fastest supercomputer, taking that crown from the United States.

In short, China made a strategic decision to leapfrog its current development path to become a high-tech economy. The implications for the United States economy should be clear. The Chinese no longer want to dominate just cost-based commodity production and let us be the innovators, they want to also win in innovation-based economic competition, exactly what so many in the United States believe is America's "sweet spot" and natural comparative advantage.

While there is a broad consensus among experts on what China is trying to do, there is considerably less consensus over whether China will be successful and whether America should be concerned. Most China experts dismiss China's efforts, arguing essentially that unless China adopts the American model of innovation that it can never be truly innovative and never be a threat. But this ignores three key issues. First, even if Chinese-owned firms do not become innovation leaders, bringing "new to the world" innovations to the market, the Chinese economy may become an innovation leader if its policies result in foreign multi-nationals moving even more innovation-based activities to China. Second, even if Chinese firms won't lead in "new to the world" innovations, many appear to have the capability of being

[1] Zizhu in English means self-determined and chuangxin means innovation.
[2] "CPC Central Committee's Proposal on Formulating the 12th Five-Year Program on National and Social Development," *Xinhua*, (adopted on 18 October 2010 at the Fifth Plenary Session of the 17th CPC Central Committee, Beijing, October, 2010).
[3] "National Medium- and Long-Term Program for Science and Technology Development of China (2006-2020): An Outline," *Wenzhou*, January 2, 2012, http://english.wzkj.gov.cn/program/program_detail.aspx?id=1.

"fast followers", especially in engineering-based innovation where China is showing real strengths. Third, even if China does not succeed in transforming its economy to an innovation-based one, their rampant innovation-based mercantilist policies are already doing and will likely continue doing considerable harm to U.S. technology companies and to the U.S. innovation economy. The bottom line is that America ignores China's innovation policies and growing innovation capability at its own peril.

China would not be the first export-oriented Asian economy to embrace an industrial policy for technology markets that could significantly harm international competitors. Japan and Korea are the most conspicuous examples. In these predecessors, global market forces and determined policy responses by other countries slowly reversed the policy mix toward a slightly more open, market-oriented direction. But just as importantly, neither nation was anywhere near as large as China is (in terms of population) and therefore their mercantilist policies did less harm. Foreign firms could afford to not be in either nation (in fact in Japan, they were largely not wanted), meaning that neither nation could use market access as lever for coerced technology transfer. China is different. It is much bigger with a potential to be more disruptive to the global economy. Its fast growing market of over 1 billion consumers is just too tempting for multinationals to boycott over egregious Chinese mercantilist policies. And the leverage of the global economic community to encourage China to more in a more open, market-oriented direction is significantly less than it was with Korea and Japan. As such, China's potential rise as an innovation competitor to the U.S. economy promises to be one of the central challenges facing the U.S. economy over the next quarter of a century.

THE SHIFT TO INDIGENOUS INNOVATION

China's MLP signaled a distinct shift in China's economic policy. But lest one think that this goal was unique to the MLP, China's 11th five-year plan refined these industries and targeted sixteen "megaprojects." Three of the sixteen are deemed classified, but the other thirteen are:

- Core electronic components, high-end general use chips and basic software
- Large-scale integrated circuit manufacturing equipment and techniques
- New-generation broadband wireless mobile communication networks
- Advanced numeric-controlled machinery and basic manufacturing technology
- Large-scale oil and gas exploration
- Large advanced nuclear reactors
- Water pollution control and treatment
- Breeding new varieties of genetically modified organisms
- Pharmaceutical innovation and development
- Control and treatment of AIDS, hepatitis, and other major diseases
- Large aircraft, and
- High-definition earth observation system[4]

China's latest five-year plan (the 12th) narrowed this focus, but recommits to these goals stating, "It is necessary to comprehensively implement the state's long and mid-term programs for science and technology." In 2011, the Chinese government committed to "place the strengthening of indigenous innovative capability at the core of economic restructuring, growth model change, and national competitiveness enhancement ….Indigenous innovation refers to enhancing original innovation, integrated innovation, and re-innovation based on assimilation and absorption of imported technology,

[4] Ibid.

in order improve our national innovation capability."[5] The proposal for the plan goes on to stress:

> We should persist in the principle of independent innovation, making key strides, of supporting development, and of providing guidance in the future, increase commonality and capability on core technology breakthrough, and promote the transformation of sci-tech results into real productive force. There is a need to accelerate promoting the state's special major sci-tech projects and implement new knowledge-innovation and technology-innovation projects in an in-depth manner. We should closely integrate sci-tech progress with the optimization and upgrading of industrial structure and with the improvement of people's livelihood, enhance the capability of making original innovation, of integrating, introducing, digesting innovation, and score new breakthroughs in such areas as modern agriculture, equipment manufacturing, ecology, environmental protection, energy, resources, information network, new materials, security, and health, overcome a number of key core technologies such as core electronic components, very large scale integrated circuit, system software, new varieties of genetically modified foods, making of new drugs. We should enhance basic frontier technology research, and strive to occupy a high ground in future sci-tech competition in life sciences, marine, space, global science, and nanotechnology… We will give play to the state's leading and supporting role for special sci-tech projects, implement industrial innovation development projects, increase taxation and financial policy support, and help high technology industry to become big and strong.[6]

The plan identifies seven priority strategic emerging industries (SEIs), aiming to increase their contribution to GDP from their then current 2 percent level (2008) to 8 percent by 2015 and 15 percent by 2020. These are: 1) energy saving and environmental protection; 2) new generation of information technology; 3) biotechnology; 4) high-end equipment manufacturing; 5) "new energy;" 6) new materials; and 7) new energy vehicles. China's State Council first identified these industries in its "*Decision on Accelerating the Fostering and Development of New Strategic Industries*" announced in 2010. To reach this goal China will provide SEIs with preferential policies, incentives, and funds worth $1.5 trillion over the next five years.[7] For the United States to match China's commitment to their SEIs on a per-GDP basis it would have to pass the equivalent of an American Recovery and Reinvestment Act every year for five years and dedicate close to 100 percent of the funds to industry. The focus on SEIs appears to be emerging as the central organizing principle for Chinese indigenous innovation policy. The Chinese government is developing a wide range of documents to articulate detailed strategic plans for each sub-industry of the seven SEIs, with the first report focused on the Chinese medical device industry. The SEI efforts are likely to focus largely on state-owned enterprises, and use discriminatory policies including government and SOE procurement, priority patent review, tax incentives, R&D subsidies and a host of other policies to help support Chinese-owned companies in these industries.

This shift to indigenous innovation can also be seen in policies toward specific industries. For example, the Chinese have targeted aviation and hope to become self-sufficient through Chinese firms. COMAC, the state-owned Chinese commercial aircraft company, benefits from a wide array of mercantilist

[5] "CPC Central Committee's Proposal on Formulating the 12th Five-Year Program on National and Social Development."
[6] Ibid.
[7] "China May Scale Back Investment in Strategic Industries," *China Briefing*, July 2011, http://www.china-briefing.com/news/2011/07/13/china-may-scale-back-investment-in-strategic-industries.html.

policies in order to foster the development of a narrow-body aircraft to compete with Boeing and Airbus.[8] COMAC's stated goal is clear: get as much foreign aviation technology as possible while seeking to develop its own "independent intellectual property rights."[9] COMAC "will commit to national and international cooperation based on the 'airframe suppliers' model to share risks and benefits, and build a system of both national and international suppliers for trunk lines, and eventually establish relatively complete service and industrial chains in the commercial airplane business."[10] In other words, the goal is to partner with some foreign suppliers to produce all kinds of airplanes, from commuter jets to wide-body, long-haul jets and to eventually produce all the supply chain inputs, including engines and advanced avionics in China through Chinese-owned companies.

In other words, China not only wants to maintain current advantages in its low value-added manufacturing (including through its refusal to allow the renminbi to appreciate other than a few percent a year) but also to gain new competitive advantage in a wide array of technology-intensive products it now imports. China's strategy for globalization is to win in almost all of the industries through its new goal of indigenous innovation. As hard as it may be for adherents of Western neoclassical economics to grasp, China doesn't want to make some things and buy others; they want to make virtually everything, especially advanced technology products and services. The result could very well be the continuation of the trend of the last decade when the U.S. manufacturing output experienced an unprecedented decline of 11 percent at a time the overall economy grew by around 13 percent.[11]

CHINESE POLICIES AND PROGRESS TOWARD INNOVATION

China is backing up its intentions to lead in innovation through a wide array of policies. These can be classified into two types: what ITIF has termed "good" and "bad" in our report "*The Good, the Bad, the Ugly (and Self-Destructive) of Innovation Policies*." In that report we developed a typology of nations' innovation policies, classifying them as to whether they help or hurt the country implementing them and help or hurt the rest of the world. "Good" policies helped both the nation and the world and include measures such as boosting government support for basic science and STEM education. "Bad" policies help the country (at least in the near to moderate term) but hurt the world and include practices such as intellectual property theft, standards manipulation and forced technology transfer. China is aggressively implementing both kinds of policies.

"Good" Policies"

In terms of "good" policies, China has made considerable progress. This is especially true with respect to support for science and the education of scientists and engineers, where we see dramatic progress.

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[8] Robert D. Atkinson, "Statement by ITIF President Robert D. Atkinson on WTO Ruling in Boeing-Airbus Dispute," (statement, ITIF, Washington, D.C., June 2010), http://www.itif.org/pressrelease/statement-itif-president-robert-d-atkinson-wto-ruling-boeing-airbus-dispute.

[9] Glennon J. Harrison, "Challenge to the Boeing-Airbus Duopoly in Civil Aircraft: Issues for Competitiveness" (technical report, Congressional Research Service, July 25, 2011), p. 11, http://www.fas.org/sgp/crs/misc/R41925.pdf.

[10] Ibid., p. 12.

[11] Robert Atkinson, Luke Stewart, Scott Andes and Stephen Ezell, *Worse than the Great Depression: What Experts are Missing About American Manufacturing Decline* (Washington, D.C.: ITIF, 2012), http://www2.itif.org/2012-american-manufacturing-decline.pdf.

- Over the past decade, Chinese R&D expenditures increased by 21 percent a year while R&D intensity (R&D to GDP ratio) increased 179 percent from 1999 to 2008.[12]

- Business R&D intensity (R&D to GDP ratio) now surpasses EU-15 levels.[13] In other words, there is more R&D investment in China as a share of its GDP than in the EU-15 countries (e.g. France, Spain, United Kingdom, etc.)

- As a result, China ranks second to the United States in total investment in R&D.

- First university degrees in natural science and engineering increased from 280,000 in 2000 to 1 million in 2008.

- China produces more engineering bachelors' degrees than Japan, South Korea, United States, Taiwan, France and Germany combined, and almost twice as many doctorates of engineering as the United States.[14]

- The number of science and engineering researchers in China doubled between 2000 and 2009.

- China ranks second behind the United States in the output of scientific and technical scholarly journal articles.

"Bad" Policies

The Chinese are not content with gradually building up their innovation capabilities, they want to jump start these, in part through bold and robust national investments, but also through a vast array of unfair, innovation mercantilist policies. ITIF documented many of these policies I n its report "*Enough is Enough: Confronting Chinese Innovation Mercantilism*." Some are briefly described here.

Government procurement focused on forced technology transfer: In 2007 China rolled out its "indigenous innovation product accreditation" scheme—a list of products invented and produced in China that would receive preferences in Chinese government procurement.[15] To be eligible for preferences, products would have to contain Chinese proprietary intellectual property rights. The central government stated that it would "delink" product catalogues and innovation and tell the provinces to do so as well, but it appears unlikely that this will actually happen in practice. What will change is that the discrimination will be done surreptitiously.

***Market Access Tied to Forced Transfer Technology*:** In the *Catalogue for the Guidance of Foreign Investment Industries (2007)* joint ventures with foreign firms have to be approved, and technology transfer agreements reached within joint venture contracts must also be submitted for approval. The

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[12] Thomas Hout and Pankaj Ghemawat, "China vs the World: Whose Technology is It?," *Harvard Business Review*, December 2010, http://hbr.org/2010/12/china-vs-the-world-whose-technology-is-it/ar/1.
[13] Robert Atkinson, "The Globalization of R&D and Innovation: How Do Companies Choose Where to Build R&D Facilities?," *Testimony before the House Committee on Science and Technology*, U.S. Congress, Washington, D.C., Oct. 4, 2007.
[14] National Science Foundation, "Science and Engineering Indicators, 2012", p. O-8.
[15] "China Policy," (description, Information Technology Industry Council, Washington, D.C.), http://www.itic.org/index.php?src=gendocs&ref=china_policy&category=trade.

guidelines encourage transfer of technology.[16] Sometimes this process takes the form of mandatory licensing of technology. Sometimes this is in the form of requirements to establish R&D facilities where the technology often "goes out the back door" in the form of Chinese researchers who leave to take the technology to Chinese firms.

Weak and Discriminatory Patent System: The global patent system means that companies that file inventions first have protection from copying. The Chinese patent system is designed to get around this restriction. Under the Chinese patent system, it is extremely easy for a Chinese firm to be granted "utility model and design patents" (as distinct from invention patents that are more akin to U.S. patents). In 2009 these "junk patents" constituted approximately three-quarters of Chinese patents issued to Chinese-owned firms.[17] This weak patent system makes it easy for Chinese firms to countersue in response to infringement suits by foreign competitors. In addition, until the Chinese government rescinded its indigenous innovation product catalogues, it intended to "give support to enterprises that develop the technology and products listed in the catalogue in the application for a patent."[18] In other words, it would have been easier to get a patent if the firm filed to protect a technology the government has identified.

***IP Theft*:** The U.S. International Trade Commission estimates that—in 2009 alone—Chinese theft of U.S. intellectual property cost almost one million U.S. jobs and caused $48 billion in U.S. economic losses.[19] Many in China even view piracy as simply a different kind of business model. There's the make/buy IP business model, and the "steal IP" business model. Both are seen as legitimate. In an article in the *Journal of Science and Technology Policy in China,* edited by the Chinese Academy of Sciences, Sheng Zhu and Yongjiang Shi write about how the cell phone "cluster" in Shenzhen called Shanzhai is "turning to the Shanzhai ethos, starting with producing counterfeited mobile phones to rebel against the expensive world-leading brands…. The Shanzhai idea of rebellion has evolved into a desire to take on global corporations by producing copies of the world leading brands."[20] The view is that this kind of rebellion is almost "Robin Hood-like" as it provides cell phones for the masses at the expense of the greedy, rich Apples, Nokias, and LGs of the world. The authors go on to note how those in central government "tend to tacit consent the phenomenon."[21]

***Domestic Technology Standards*:** China uses home-grown standards as a way to gain competitive and hopefully monopolistic advantage. As the MLP stated, "The state should establish a platform to service standards, support and speed up the transformation of advanced foreign standards into domestic standards, and give key support to enterprises that promote the formation of technological standards

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[16] Terence P. Stewart, et. al., *China's Support Programs for High-Technology Industries Under the 12th Five-Year Plan,* (Washington, D.C.: Law Offices of Stewart and Stewart, June 2011.), p 86.
[17] James McGregor, "China's Drive for 'Indigenous Innovation' A Web of Industrial Policies," (working paper, APCO Worldwide), p. 15, www.uschamber.com/sites/default/files/reports/ 100728chinareport_0.pdf.
[18] "Create and protect IPR," *China's Guideline for Implementing Scientific Development Programme (*paragraph 33 of Section VI, 2006).
[19] Katherine Linton, Alexander Hammer, and Jeremy Wise, *China: Effects of Intellectual Property Infringement and Indigenous Innovation Policies on the U.S. Economy*, (Washington, D.C.: U.S. International Trade Commission, May 2011), http://www.usitc.gov/publications/332/pub4226.pdf.
[20] Sheng Zhu and Yongjiang Shi, "Shanzhai manufacturing- an alternative innovation phenomena in China: Its value chain and implications for Chinese science and technology policies," *Journal of Science and Technology Policy in China* 1, no.1 (2010), p. 31 and 46.
[21] Ibid, p. 35.

with ourselves as the dominant factor through re-innovation." The 12th Five-Year Plan proposed to "encourage the adoption and promotion of technical standards with indigenous intellectual property rights."[22] These non-tariff barrier tools are becoming a more central part of China's mercantilist strategy. As China scholar Dieter Ernst points out, the Standards Administration of China justifies its nationalistic and protectionist standards strategy on the grounds that "China's accession commitments to the WTO have substantially reduced the use of most other trade restrictions such as tariffs, import quotas, and licensing requirements."[23] As a result, China lags significantly behind other economies in developing a pro-innovation standards policy. According to the WTO, in 2007, around 14.5 percent of national standards, 15 percent of professional standards, and 19 percent of local standards in China were mandatory.[24] Moreover, voluntary standards can become mandatory if they are referenced in mandatory conformity assessment procedures. In 2007, only 46.5 percent of Chinese national standards were equivalent to international standards.

These "bad" mercantilist policies are all designed to ensure that the Chinese economy produces significantly more technology-based products and imports significantly fewer. For example, through the SEI initiative, China is working to ensure that 30 percent of domestic semiconductor demand is met with Chinese designed and produced semiconductors by 2015, and that 80 percent of flat panel displays consumed in China be produced domestically by 2015. It is creating a domestic Chinese "IT could" based on Chinese technology and IP. Brute force and massive subsidies may not be as elegant or efficient as an entrepreneur working in a garage in Silicon Valley, but they can still be effective.

Innovation Results

China's emphasis on science, technology and innovation has paid off, at least in terms of some innovation indicators. ITIF's *Atlantic Century* report ranks nations on sixteen variables related to innovation and competitiveness, including corporate and government R&D funding, scientists and engineers, new business formation, productivity growth, and others. It also compares nations on overall combined scores in 2011 and in the early 2000s to compare rates of progress. China ranked first among 44 nations on its rate of progress since the early 2000s. In contrast, the United States ranked second to last, ahead of only Italy. Georgia Tech's *2008 High-Tech Indicators* study, found that China improved its technological standing by 9 points (on a scale of 100), moving the nation ahead of the United States in technological capability for the first time. In a survey conducted by Battelle of 713 researchers from around the world on what nations lead in ten different technology areas, China was in the top five nations on all ten areas, and ranked as high as second on agriculture and food production, commercial aerospace and military/aerospace.[25] We can see further evidence of China's progress in a number of indicators:

- China's global share of high technology manufacturing value added increased from 3 percent in 1998 to 19 percent in 2010.[26]

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[22] Stewart, et. al., *China's Support Programs for High-Technology Industries Under the 12th Five-Year Plan*, p. 6.
[23] Dieter Ernst, *Indigenous Innovation and Globalization: The Challenge for China's Standardization Strategy* (San Diego: IGCC, 2011), p. 24, http://igcc.ucsd.edu/assets/001/501951.pdf
[24] World Trade Organization, *Trade Policy Review: China* (Geneva: WTO, 2010), http://www.wto.org/english/tratop_e/tpr_e/tp330_e.htm; World Trade Organization, *Trade Policy Review: China* (Geneva: WTO, 2008), http://www.wto.org/english/tratop_e/tpr_e/tp299_e.htm.
[25] "Engaging the Global Researcher," *R&D Magazine*, December, 2011, p.35.
[26] National Science Foundation, *Science and Engineering Indicators, 2012*, p. O-15.

- China's trade balance in high technology goods increased from approximately zero in 1998 to around $155 billion in 2010.[27]

- China's total patent volume rose at an annual rate of 26.1 percent from 2003 to 2009.

- China now has as many offshore R&D operations of U.S. multinational firms as does Europe.[28]

- By 2008, the U.S. share of global machine tool production had fallen to 5 percent (half its share in the 1970s), as China's share rose to 35 percent.

- China's market share of global printed circuit board has grown from 7 percent in 1999 to over 31 percent in 2008.

- In 2007, 40 percent of the semiconductor fabrication plants under construction in the world were located in China, with just 8 percent being built in the United States.

- China became the world's leading producer of solar panels in 2009, the leading producer of wind turbines in 2010, and intends to become the world's largest manufacturer of lithium ion batteries sometime between 2015 and 2020.

Why Do So Many in the United States Dismiss China's Innovation Capabilities?

Despite all that China is doing to compete and win in innovation-based production, the consensus view in Washington is that China poses no real threat to the U.S. innovation-based economy. This compliancy comes from several sources.

First, over the past half-century, the United States has developed an attitude that we always have and always will lead at innovation. This has fostered an entitlement mentality which assumes that other nations can never really "touch us" when it comes to innovation. Economist Irwin Stelzer declares, "America remains the source of most of the world's innovations and the home of most of its great entrepreneurs."[29] RAND confidently affirms that "Despite perceptions that the nation is losing its competitive edge, the United States remains the dominant leader in science and technology worldwide."[30] But to paraphrase the warning on investment prospectuses, past performance is no guarantee of future performance.

Second, one reason America is supposedly destined to lead on innovation is because purportedly only the "Washington economic model" can produce real innovation. Under this model policies that promote open trade, free markets, free speech, rule of law, strong intellectual property protection, and support basic "factor conditions" such as investments in science and education, are not only the keys to innovation, they are the only way to generate innovation. Other models based on more interventionist policies by definition cannot succeed. And according this view, since China follows a "Beijing consensus" model, not a "Washington consensus" model, it simply will never develop an innovation

[27] National Science Foundation, *Science and Engineering Indicators, 2012*, O-19.
[28] "China's R&D Momentum", *R&D Magazine*, December 2011.
[29] Irwin Stelzer, "Chinese Chess," *Weekly Standard*, December 18, 2010, http://www.weeklystandard.com/blogs/chinese-chess_523513.html.
[30] RAND Corporation, "U.S. Still Leads the World in Science and Technology: Nation Benefits From Foreign Scientists, Engineers," news release, June 12, 2008, http://www.rand.org/news/press/2008/06/12.html.

economy. As Adam Segal, a Senior Fellow at the Council on Foreign Relations writes in his book *Advantage: How American Innovation Can Overcome the Asian Challenge*, "without respect for rule of law and IP rights, as well as a culture of individual initiative and openness, these steps will not produce the intended results."[31]

He goes on to write, "History shows that it will be difficult to build a truly innovative economy while tightly controlling information." For Segal and other defenders of the Washington consensus America's cultural values of individualism, social mobility, entrepreneurship, and limited barriers to market access will provide a significant advantage over China, even if the latter invests massive amounts in innovation and enacts rampant innovation mercantilist policies.

Segal is not alone. Chrystia Freeland, an editor for Thomson Reuters, writes in a *Washington Post* editorial that: "China is an object lesson in the threat that centralized, authoritarian states pose to revolutionary technological development."[32] She goes on to laud the American model: "The American political economy has many flaws—collapsing infrastructure, a hollowed-out middle class. But America has one great virtue that no other country has yet to replicate: When it comes to innovation and its translation into things people want, America is unbeatable." If Freeland defines "unbeatable" as having been beaten by forty-two other nations, in the rate of progress on innovation-based competitiveness in the last decade), then yes we are "unbeatable."

One of many problems with these sanguine views is that they too narrowly define innovation to include "first to the world" new products, services and business models. To be sure this is an important component of an innovation economy and on this score, China is lagging. At this time, China lacks an innovation system that would enable it to produce large numbers of "new to the world" innovations, in products, services, processes or business models. The elements of such a model include risk taking entrepreneurs, a robust venture funding industry, top quality technology managers, and robust regional learning systems where information and innovations flow easily between various players. The major investments they made to model Silicon Valley have so far not been very successful, turning into largely real estate plays.

Chinese patent filings illustrate the challenges. According to the OECD, in 2008 there were only 473 triadic patent filings (patents signifying more fundamental innovations) from China versus 14,399 from the US, 14,525 from Europe, and 13,446 from Japan. Data for patent grants in 2010 by individual offices present a similar picture. Patent offices outside China have granted only 1 per cent of patents to China. Half of these patents were granted to subsidiaries of foreign multinationals.

But it is important to recognize that Chinese officials are well aware of these weaknesses and are aggressively working to remedy them. China, for example, has made huge strides on building a world-class university and research lab system in the past three decades.

More importantly, "new to the world" is only one component of an innovation economy. Another component is *innovation adaptation*, defined as taking complex production system that are relatively well defined and building products and related processes. This is a major activity of engineering and development centers of multinational

[31] Adam Segal, *Advantage: How American Innovation Can Overcome the Asian Challenge* (New York: W. W. Norton, 2011).
[32] Chrystia Freeland, "China's Economic Model Isn't the Answer for the U.S.," *The Washington Post*, August 30, 2010, http://www.washingtonpost.com/wp-dyn/content/article/2010/08/29/AR2010082902898.html/.

enterprises. It also is common among Chinese entrepreneurs, including the use of reverse engineering and copying of international products and processes. And this is where' China's real strength in innovation lies, in what can be called engineering-based innovation.

We see this in a number of statistics. In terms of science and engineering journal articles, China is only slightly ahead of Japan and considerably behind the United States. But when looking just at engineering articles, China is about double of Japan and only about 20 percent less than the United States.[33] Its higher education system is focused principally in engineering, with 30 percent of all first time degrees in engineering, and 60 percent of science and engineering degrees. In contrast, the equivalent percentages in the United States are 4 percent and 14 percent.[34] This means that China is well positioned to win in producing advanced technology products, even if it doesn't innovate them in the first place.

Chinas strong engineering talent pool combined with its vast array of mercantilist policies means that China attracts foreign multinational innovation and technology activities. Even if China only becomes a vibrant high-tech, "branch plant" economy with multi-national firms establishing laboratories and advanced production facilities there and does not produce a significant number of Chinese owned innovation-based multinationals, the damage to the U.S. economy will be significant as America loses advanced technology production jobs and establishments.

Finally, even if Chinese policies do not succeed at creating an innovative Chinese economy, the mercantilist portion of their policies do real damage the U.S. economy by reducing U.S. corporate profits, lowering productivity and innovation, increasing the U.S. trade deficit and reducing higher wage U.S. jobs.

Conclusion

It is difficult for many American economic and trade experts to fully grasp the implications of what China is doing. To these experts, economic policy is about enhancing consumer welfare by enabling markets to efficiently allocate goods and services in well-defined, legally protected markets. Borrowing from Ricardo's writings on free trade, if a nation's natural comparative advantage is in wine (e.g. in China's case, commodity production and assembly) then it should export wine to pay for its textile imports. If the Chinese government is misguided enough to subsidize their high-tech exports, the thinking goes, not only with this backfire since government can't change comparative advantage, but American consumers are the better off for it.

Many American trade and economic policy experts refuse to acknowledge that Chinese economic policy is based on a fundamentally different conception than America's of economic welfare and of how to achieve it. Because of this, when they see what they believe to be market distorting, welfare-reducing "innovation policies" from the Chinese government, they believe that China not yet learned the merits of the superior and correct rules-based system. But the reality is that China appears to have has little interest in adopting the Washington consensus approach to economic policy. They don't want to make just "wine" they want to make 747 jet airplanes. And if they continue their current "good" and "bad" innovation polices they are likely to do so.

[33] National Science Foundation, *Science and Engineering Indicators, 2012*, p. O-10.
[34] Ibid, p. O-7.

HEARING CO-CHAIR GOODWIN: Dr. Breznitz.

STATEMENT OF DR. DANNY BREZNITZ
ASSOCIATE PROFESSOR OF INTERNATIONAL AFFAIRS
GEORGIA INSTITUTE OF TECHNOLOGY

DR. BREZNITZ: Thank you.

Distinguished members of the Commission, thank you for the opportunity to testify. I am honored to have such a chance.

There are four central points to be made when considering China's innovation capabilities and the challenge they present us.

First, globalization has changed the manner in which innovation is carried out around the world. We have a new production system of global fragmentation where locales have been specializing in specific stages of particular industries and not the complete value chain. As such, each place specializes in particular innovation now capabilities.

This has led to true economic interdependencies because it's no longer that we are dependent on trade to become wealthy; we now cannot even produce "our" own products without our partners. Nonetheless, this does not mean that the world is guaranteed prosperity. Interdependency leads to sharp divergence between the economic and political logics and, hence, carries with it a new dimension of insecurity that can lead to a quick and destructive escalation.

Despite the long-term intention in heavy investment by the Chinese central government developing what they call "indigenous innovation," China's true innovation competitive edge is mastering, just like Rob said, the art of second- generation innovation, including the mixing of established technologies and products to come up with new solutions.

This system, built from the bottom up, against the will of the central government, is China's greatest strength and the real competitive challenge facing us. At the same time, "core" technologies and novel product innovations are still rare and difficult to achieve in China.

Therefore, we should focus less on China's attempt to outdo Silicon Valley and more on China's capabilities in the commercialization, improvement and application of technologies first developed here. This is our real long-term challenge if we wish to capture more of the value, including jobs, of our innovation.

Innovation is the key to sustained economic growth. However, innovation needs to be understood more broadly. The globalization of R&D design, production and manufacturing requires a new approach to innovation policy, one focusing, just as Robert said, on second generation--process, incremental, and production innovation--in order to avoid the risk of losing jobs and industrial capabilities essential to our competitiveness and security.

To excel in each state of production, a locale must specialize in and master a specific set of skills. Any of those innovation strategies can provide lasting competitive advantage for a firm or a region. But the distribution and type of economic returns they offer differ widely. For China, specialization in later states of production means lower profit margins, but also large numbers of lower middle and middle class jobs. Who of us can judge whether the future belongs to Cisco or Huawei? Maybe the

future belongs to both of them.

Trade leads to integration of the world's major economies through mutually beneficial exchange. Today, interdependency is heightened more than ever before. Firms and countries just lack the ability to produce complete products. They are reliant on foreign partners. As such, war supposedly would only lead to mutual bankruptcy. Nonetheless, there is a sharp divergence of the political versus the economic logic.

The political logic makes us keenly aware that interdependency equals growing vulnerability, and that trusting the wrong partner can lead to a complete destruction of a society.

Under such circumstances, even minor political-economic misunderstanding can, and as a matter of fact should, be expected to quickly escalate. The only way to ensure long-term stability of such a system is to build specific institutions whose aim is to handle constant friction and prevent rapid escalation from reaching levels that might undermine the whole system.

If we measure success in innovation as the creation of novel products or services based on the ownership of intellectual property, then to date, China has failed. We will be hard-pressed to name a single significant wholly Chinese novel development.

However, China has developed a formidable capacity to innovate in different segments of the R&D and production chain. Examples are China's growing global market share of uninterrupted power supply, which you probably don't care about unless you go under the knife in surgery or want to have a space program or Huawei-controlled domination of unassuming internet dongles niche. Neither of those products were invented or first produced in China.

Chinese firms have also become the masters of "design for production." By mastering this skill, they have ensured a continued advantage in manufacturing, unrelated to low-cost labor. Indeed, this technology transfer has allowed Chinese companies to quickly seize on new technologies and, as a matter of fact, American venture capitalists working in China are one of the most important of such mechanisms.

This is not to say that China has not been attempting to develop novel innovation capabilities. Through many of its revisions, the policy of indigenous innovation remains devoted to freeing China from relying on foreign technologies. In many cases, this actually means reinventing the wheel, developing new CPUs rather than buying Intel.

As cloud computing appears set to become the new paradigm of managing, collecting, and processing of information, China's security-conscious government takes an active interest in new technologies.

However, China's capabilities in production and large markets, as well as political commitment, give it strong advantage in developing new technologies elsewhere at scale. Clean technology networks will probably be first deployed in China on a large scale. It is the large-scale deployment phase where many of the most important opportunities for innovation, improvement and learning occur.

Consequently, we should expect China to lead the United States in certain technologies, even if most of those technologies were first developed here. Signs can already be seen in both wind and solar power.

I'm not going to talk about the standards, which have not been really helpful for China, and I will just say that the SOEs are a complete failure. Both Huawei

and ZTE did not start as SOEs and both are successful companies.

I will just say that it might be when dealing with the challenge that China's innovation rise presents us, we should paraphrase on an insightful quote attributed to Charles Darwin: "It is not the strongest of the nations that survive, nor the most intelligent; it is the one most adaptable to change."

Thank you so much.

PREPARED STATEMENT OF DR. DANNY BREZNITZ
ASSOCIATE PROFESSOR OF INTERNATIONAL AFFAIRS
GEORGIA INSTITUTE OF TECHNOLOGY

Testimony of
Dan Breznitz
Associate Professor
The College of Management
&
Sam Nunn School of International Affairs
Georgia Institute of Technology
to the
US-China Economic and Security Review Commission
May 10, 2012

Chairman Shea, Vice Chairman Reinsch and distinguished members of the Commission, thank you for the opportunity to testify on the topic of China's innovation capabilities. This is my first opportunity to testify before this body, and I am honored to have such a chance.

There are four central points to be made when considering China's innovation capabilities and the challenge they present for the United States:

1. Globalization has changed the manner in which innovation is carried out around the world. A new production system of global fragmentation evolved where locales specialize in specific stages of particular industries and not the complete value chain. As such, each place is specializing in particular innovation capacities that, ideally, lead different national economies to excel in their chosen stage of production.

2. The rise of global fragmented production of both goods and services has led, for the first time in history, to true economic international interdependency. It is no longer only that we are dependent on trade in order to continue to be wealthy; we now cannot even produce "our" products and services alone. Nonetheless, this does not mean that the world is guaranteed peace and prosperity, far from it. True interdependency lead to sharp divergence between the economic and political logics. Where one highlights the gains, the other makes highlight the costs. Accordingly, this new system brings accentuated dimensions of insecurity that can lead to rapid destructive escalation. The economic history of the first economic globalization and its violent end in World War I, attest to that only too well.

3. Despite the long-term intentions of, and heavy investment by, the Chinese central government developing "indigenous innovation," China's true innovational competitive edge is mastering the art of second generation innovation, including the mixing of established technologies and products to come up with new solutions, and the science of organizational, incremental, and process innovation. Thus, China's innovation capabilities are not solely in process (or incremental) innovation but also in the organization of production, manufacturing techniques and technologies, delivery, design, and second generation innovation. This system, built from the bottom up by masses of entrepreneurs, is China's greatest strength and the real competitive challenge facing us. At the same time, "core" technologies and novel product innovations are still rare and difficult to achieve in China.

4. The United States should focus less on China's attempt to outdo Silicon Valley and more on China's capabilities in the commercialization, improvement and application of technologies first developed in the United States. This is our real long-term challenge and the key one if we wish capture more of the value, including job creation effects, of our own novel innovation.

The world has changed. China is a major factor of, and a great beneficiary, of that change. In this testimony, I briefly outline the changes brought by our new globally fragmented production system, the political impact of true, hopefully lasting, deep economic integration and interdependency, the real strengths and challenges of China's innovation system, and the actual competitive challenges facing the United States.

Innovation

Innovation is the key to sustained economic growth. However, innovation needs to be understood more broadly than it typically has been. A pervasive misconception among policy makers and academics has made excelling in innovation – defined solely as the creation of new technologies, services, and products – the holy grail of economic growth. Accordingly, too often conversations about innovation focus on novel breakthrough developments that give rise to "game-changing" technology. This kind of innovation characterized the American economy for the past century and has generated enormous wealth and value for the nation. Nevertheless, the globalization of design, production, sophisticated manufacturing, and distribution requires a new approach to a second form of innovation – in second generation, processes and production, as well as incremental product innovation – in order to avoid the risk of losing jobs and industrial capabilities essential to the competitiveness of the United States economy. The car was a great novel innovation, but none of us would have wished the innovations in the automobile industry to stop with the Ford Model T.

To understand innovation in China, we must understand the major shift over the last few decades away from vertical co-located integration of firms and productive activities toward global fragmentation of production. Lower transportation costs, trade barriers, and significant political changes, coupled with a true revolution in information technologies, enabled organizations to standardize productive activities into discrete modules which can be outsourced and, increasingly, off-shored. A firm no longer needs to master all stages of production in order to participate in, or even lead, a given industry such as automobiles or semiconductors. Nor does a would-be startup need to raise the billions of dollars necessary to build a modern manufacturing facility. For example, in semiconductors a small team of talented designers can plan out the chips and have them fabricated in dedicated facilities, which use photomasks produced by specialized producers, on equipment bought from purpose-devoted manufacturers, and finally assembled and tested by firms whose focus is solely on these activities. Each of these activities is increasingly concentrated in different countries, from the United States in design to fabrication in Taiwan. In today's global economy, different countries and regions specialize not only in particular industries but in specific stages of production within particular industries. Novel products and services are produced globally without being made in their "home" country. Many firms never produce their "own" products. A global system of highly focused firms, perform these tasks far more efficiently and cheaply than a new innovator without such skills. As a result, there are many successful national models of innovation, each focusing on specific stages of production.

Take Apple, the quintessential Silicon Valley company. IIn the past Apple produced at least some of its products, but today, not only do they not produce their own products, but some of the design for the iPod, iPhone and iPad was bought as an outsourced service. In the United States, where deep pools of creative human talent are available, Apple engages in high end product definition and final sales and post-sales services through its different platforms. Throughout Asia, components for the

various iProducts are manufactured in discrete stages in different locations, before being snapped together – most notably in Foxconn's massive export-processing plants in China. Certainly, Apple retains the intellectual property rights to these products and receives the bulk of the profits. However, the greatest number of jobs is generated not in the United States but in Asia, and while many of them are not jobs we would consider good, many of them would have been considered a good engineering position in the United States. Furthermore, as we can now see in the automotive production industry, sometimes it is not the firms in the pinnacle of "innovation" who have the most power, and accrue the most profits, over the network. Novel innovation and design might, and to some degree already, become just another service to be bought and sold in the global market.

To excel in each stage of production, a locale must specialize in and master a specific set of innovational skills. To thrive, a region specializing in high-end product definition must hone innovative capabilities in long-term research and new product development. On the other hand, a region specializing in abrication and system assembly should develop innovative capabilities to improve the efficiency of production in terms of capital, resource and labor inputs as well as improving time to market and quality. Any of these innovation strategies can provide lasting competitive advantage for a firm or a region but the distribution and type of economic returns they offer differ widely. For the United States, specialization in high-end R&D and novel product innovation provides the highest profits but these are often restricted to a smaller number of highly skilled individuals. For China, specialization in later stages of production means lower profit margins and stiff competition among firms but also large numbers of lower middle and middle class jobs. However, it is not clear whether and institutional system geared toward one, with specialized financial vehicles, network structure, and regulatory regime, can excel in both. It is almost unimaginable for a Chinese entrepreneur, working in China, to follow the same business models she would have followed had she stayed in the United States. In the United States, where the innovation system is focused on novelty with access to true venture capital, and our particular business and regulatory system, make it much more appealing to focus on novel-Intellectual Property Rights (IPR)-rich and production poor enterprise, while business plans necessitating building and managing large scale production facilities would never have the same appeal. In China the opposite is true. Nevertheless, since both business plans rely on the development of unique innovational capacities supported differently by the competitive advantage of the home regions, both can feasibly lead to the creation of a global leader. Who of us can judge whether the future belongs to Cisco or Huawei, Geely or GM? Maybe the future belongs to them all?

Fragmentation Creates Real Interdependency

In 1909, Norman Angell wrote a fierce, logical, and extremely convincing argument, showing how trade led to the integration of the world's major economies through mutually beneficial trade and finance – and as such war would only lead to mutual bankruptcy and social despair. Interdependence, therefore, eliminated any economic rationale for war. Consequently, he vehemently argued, war between the European powers has become completely unlikely. The book had become a best seller and widely read among the European elites at the time, repeatedly mentioned in parliamentary debates. One of its arguments, that war will only lead to mutual bankruptcy and not economically benefit the winner, turned out to be painfully true, and yet the European powers went on to wage two utterly devastating World Wars.

The core reason for this devastation is the sharp divergence of the political versus the economic logic with regards to growing interdependence. If the economic logic leads us to collaborate and, hopefully, grow rich together, the political logic makes us keenly aware that interdependency equals growing vulnerability, and that trusting the wrong partner can lead to a complete destruction of our

society.

Today, interdependency is much more accentuated then before World War I. While German and British firms traded in the years leading up to World War One, trade was often in completed goods. Under fragmentation of production, firms and countries lack the ability to produce a complete product independently within their borders. They are reliant on foreign partners to provide critical components and services in order produce goods and services. The same multinationals which develop new technologies in the United States would not be able to produce and stay profitable without China. In a world of fragmented production, HP, Apple and Cisco would find it extremely difficult to operate without their Chinese partners. And in the same way, their Chinese partners would find it difficult to operate without them – a true interdependency. Although concentration of production skill and capacity in China is a source of strength, without massive orders from companies based overseas, China's industrial growth and profits would be undermined.

However, our current more absolute interdependency increases political concerns about security and economic vulnerability in case of crisis or foul play. Our interdependency means that for every nation, especially the United State and China who sees themselves as major powers, even minor political-economic crises can, and as a matter of fact should be expected to, quickly escalate as both parties fear the repercussions of backing down or losing access to critical resources. In the Sino-US relationship, this dynamic of economic interdependence and political tension is clearly visible. The recent row over the export of rare earth metals between China and Japan illustrates the political risk inherent in economic interdependence. Reliance upon foreign nations for critical components or services heightens political tensions even as economic relations become ever tighter, more productive, and profitable. The only way to ensure long-term stability of such system is to build specific institutions whose aim is to handle these kinds of constant friction and prevent rapid escalation from reaching levels that might undermine the whole system.

China's Innovation Capabilities

Foreign observers studying China's innovation capabilities tend to measure China's capabilities against the gold standard of Silicon Valley. Some find a comparable analog within China and argue the country has discovered the "secret sauce" of innovation. They conclude that with its massive human, capital and physical resources, China will soon be the world's leading technology and innovation power. Others, however, note China's struggles with intellectual property rights protection, media control, rote-memorization-based education, horrific financial system and political interference arguing that China's innovation bona-fides are highly overstated.

If we measure success in innovation as the creation of novel products and services based on the ownership of core intellectual property, then to-date China has failed. Scholars and media observers familiar with China have been hard-pressed to name a single significant wholly Chinese novel development. It is therefore easy to dismiss China out of hand and argue that it does not innovate and indeed that it is heading straight for the middle-income trap: finding that it is too expensive to compete in labor intensive low-value added sectors, but lacking the capabilities to "innovate" and thus compete in high technology industries.

However, such predictions do not consider China's strengths or the tectonic changes in the ways in which innovation takes place worldwide. As China has become the global center for many different stages of production, it has developed a formidable capacity to innovate in different segments of the research, development and production chain. These are as critical for broad-based economic growth – perhaps more so – as many novel-product innovations. China's national model involves mastering second-generation innovation, including the mixing of established technologies and products to come up

with new solutions, examples of which are China's growing global market share of Uninterrupted Power Supply (UPS) systems, or the domination of Huawei in the unassuming internet Dongles niche, neither of these products were inventing or even first produced by Chinese companies, plus organizational and process innovation. China's companies are much better at developing and improving existing products, processes and services (or localizing and indigenizing them) than at inventing new ones. They are increasingly capable of seizing on new technologies and using policy and market mechanisms to encourage their implementation at scale. Chinese technology companies shine by developing quickly enough to remain at the cusp of the global technology frontier without actually advancing the frontier itself. Thanks to their position at the center of the fragmented global manufacturing process, many Chinese companies excel in a wide array of secondary innovative activities, and these create significant economic value for the nation. For example, China's firms (both wholly indigenous and those established as foreign subsidiaries or joint ventures) have become masters of "design for production." By mastering this skill, they have ensured a continued advantage in manufacturing, one wholly unrelated to the low-cost labor or government subsidies to which China's competitive strength is often attributed.

Since China suggests there are in fact multiple types of innovation in which an economy can specialize, the corollary is that policy makers need to rethink what innovation means and adjust national indigenous innovation strategies accordingly. Where the goal is national economic growth and job creation, emphasizing novelty may not be the best strategy. China's strength is exactly that it is not particularly strong in novel-product innovation.

This is not to say that China has not been attempting to develop such core innovative capabilities. Throughout its many revisions, the policy of "indigenous innovation" remains essentially devoted to freeing China from reliance on foreign core technologies. In many cases this means reinventing the wheel – developing new advanced Central Processor Chips rather than purchasing them from Intel or AMD. The 2006 "15-Year Mid-to-Long Range Plan" called for 10 megaprojects where China would develop indigenous technologies such as wide-body aircraft. The current five year plan specifically mentions achieving breakthroughs in new technologies in environmental protection, next generation information technology, bio-science, advanced equipment manufacturing, new energy, new materials, and alternative energy vehicles.

China's 12th Five Year Plan targets Cloud Computing as one of the next generation information technology sectors to promote. As Cloud Computing appears set to become the new paradigmatic method for the managing, collection and processing of information, China's security-conscious government takes an active interest in the technology. This is married with a strong belief in the importance of developing capabilities for and deployment of the "Internet of Things." Although neither technology is fully established nor are the commercial applications fully appreciated even in the West, Chinese firms – most notably Inspur and China Mobile – are developing their own versions of Cloud solutions and deploying them at scale. Their target markets differ. While China Mobile mostly markets to first and second-tier urban areas, Inspur's cloud solution is being marketed to third and fourth-tier Chinese cities. Inspur's solution options include "media clouds" which are a means of managing the three-way integration of phone, data, and broadcast by centralizing the storage and dissemination of all types of information. By selling to government clients in China's interior, Inspur hopes to replicate Huawei's success in building market share and brand recognition before turning to the major East Coast urban markets. Interestingly for the United States government, such business models as Media Clouds, and the control of State Own Enterprises, such as China Mobile on the biggest Clouds in China, also means that the ability of the government to tighten its information control, and collect granulated information on the state usage of each and every citizens in rapidly expanding.

China's recent history of unilateral technology development efforts increases the likelihood of a

major domestic push in cloud computing. In 2009, China developed and deployed two information security and control technologies for the domestic market. The first, Green Dam, was an Internet filtering software designed to prevent users from having access to pornography and politically sensitive content. The domestic public uproar over the technology, as well as foreign opposition led the central government to shelve plans to mandate implementation of the control software. Later that year, however, an ISP-level filtering software call Blue Dam was mandated and implemented successfully without much fanfare but achieving the same results. In the interests of information control and security, we will likely see high levels of investment and central state attention paid to Cloud Computing and related technologies. However, although there will be state emphasis on developing technologies in these areas, this is not China's strength nor is it the area which should arouse the most concern in the US.

While projects such as developing new wide-body aircraft or investing in the space program and indigenous processors for computer servers may appear to be expensive diversions, China's capabilities in production and large markets as well as political commitment afford it strong advantages in deploying new technologies developed elsewhere at scale. As noted in recent research by Ed Steinfeld of MIT, clean technology, smart grid, and electric vehicle charging networks will likely first be deployed in China as large-scale systems. It is in the deployment stage, especially large-scale deployment that many of the most important opportunities for innovation, improvement and learning occur. Consequently, if things would stay at current trends we should expect China to lead the United States, even if most of these technologies were first developed here. This can already be seen in both wind and solar power where China is now the world's largest producer and consumer of such equipment. For multinational corporations (MNCs) which develop these technologies, they will likely locate their R&D and engineering centers in China as the capabilities, application, and market for such scale knowledge will be there.

In China's pursuit of new technologies, the greatest threat to the prosperity China currently enjoys is, ironically enough, China. Media and academic reports which state that China's central government favors large state-owned enterprises (SOEs) at the expense of private small and medium-sized enterprises (SMEs) are generally correct. While some of these large SOEs, such as China Mobile have achieved successes in deployment and utilization of new technologies, many are only marginally profitable and often struggle to develop or deploy new technology. China's private enterprises and certain locally- or regionally-owned SOEs have a much better track record in innovation. These enterprises emphasize China's strengths in incremental improvement, large-scale deployment of foreign technologies and rapid following of new trends and inventions abroad.

China's most famous telecommunications equipment firms – Huawei and ZTE – achieved their successes not through invention of wholly new technologies but rather through development of rugged and inexpensive versions of foreign technologies – digital switches and PHS phones in particular. By emphasizing less developed markets and aggressively reinvesting profits in technology improvement and human resource upgrading, both firms have now become capable international competitors. However, during their formative stages, neither was a central government-favored national champion. Their success came in spite of the central government, rather than because of it. State champions favored since the 1980s such as Great Dragon and Potevio continue to struggle.

China's approach to forcing technology capability upgrading the development of indigenous novel product innovation capabilities has had few successes. Historically, the main approach for technology upgrading was through mandated joint ventures between foreign and domestic state-owned firms. However, as seen in the automobile industry, these joint ventures have tended to make the Chinese partner more dependent on foreign technology and to even lose the independent development

capabilities they may have once had. The ready availability of high-end and highly marketable foreign technology makes it easier for Chinese firms in joint ventures to rely on their foreign partners rather than upgrade their innovation capabilities.

More recently, Chinese commercial policy has attempted to mandate the transfer of certain key technologies by foreign firms in exchange for market access. While the so-called "market access for technology" arrangement is officially banned under the WTO, foreign MNCs in China insist that it remains an unwritten rule, especially for firms hoping to access the coveted government procurement market. The procurement market itself has been a fractious issue as China has tried to give preference to state and domestic firms – those with "indigenous technology" over foreign firms in the bidding process. Although indigenous technologies such as WAPI and Red Flag Linux were favored in procurement, this has not resulted in their successful commercialization. As a means of technology upgrading, neither approach has yielded strong results in terms of creating ground-breaking technologies or globally competitive firms.

The most recent policies to promote indigenous innovation involve the active hand of the central government in setting technology standards. China's standardization law mandates government representatives initiate and participate in any official standards development effort. Under the widely held belief that first class companies like Microsoft or Qualcomm set industry and technology standards, China actively encourages its firms to participate in standards development. The Ministry of Industry and Information Technology, the State Administration of Radio, Film and Television, and the Ministry of Science and Technology are active sponsors of industry standards.

Research from Scott Kennedy and Pete Suttmeier has shown that especially in information technology, China has attempted to set unique indigenous standards which favor home-grown technology over the foreign analog. However, to date, none of these efforts has been successful in promoting a Chinese standard as a globally competitive and accepted standard. While some, such as TD-SCDMA, have been approved as foreign standards, only the most recent 4G TD-LTE standard has garnered support from overseas firms interested in developing or utilizing technology and equipment compatible with the standard.

Standards policy in China does not directly exclude foreign participation but as a technology development policy, it gives preference to domestic firms. In many standards setting working groups and technical committees, foreign MNC representatives are only observer members. In others, there have full voting rights but are not part of the "core members committee" which sets direction for the standard and includes the government representative. This limits their ability to set the direction of the standard but does not preclude the inclusion of their patents as essential embedded technologies in the standard. In many Chinese standards, including TDSCDMA, foreign technologies account for the majority of essential patents in the standard protocol.

The motivation for technology standards development in China shapes the types of policies which are actually carried out. While developing indigenous innovation and technology development capabilities is important, a top priority is finding ways to lower the royalties Chinese manufacturers must pay to produce foreign standards-compatible products. Given the location of Chinese firms in fragmented global production networks, royalties constitute a major cost of production. In the 2000s, the DVD player industry's annual royalty payment exceeded the entire industry's total profits. Since the 1990s, Chinese standards development efforts have been very successful in reducing the royalties owed for producing products compliant with foreign standards with embedded technology. In DVD players, telecommunications equipment and media encoding, China's standards efforts have been a strong influence in setting lower royalty rates.

Implications for the United States

To appreciate and prepare for the challenge offered by China's innovation, the United States needs to understand the Chinese mode of innovation, and fully appreciate the changes in the global production of innovation. We need to look at China's actual capabilities rather than those we might fear, or even those that are being actively pursued and promoted by the central government (rather unsuccessfully in the last two decades one might add). China's official pursuit of novel-product innovation capabilities is not China's predominant strength. It does not matter that China may soon file or receive the most patents worldwide or the most scientific publications, since this upsurge should be seen more as the response of rational economic and academic actors to new incentives and requirements by the state. Furthermore, the patent statistics are heavily skewed by the prowess and aggressive patenting by a few firms – Huawei most prominently. Fears that China will replicate or even surpass Silicon Valley in rapid novel-product and novel-idea innovation are misplaced and miss the entire point of China's successes and capabilities.

Rather, the issue is that China's successes in second-generation innovation and fast followership mean it will achieve much greater economic growth benefits from new technologies. By deploying new technologies at scale and producing them for the world market – as the only region with the necessary complete production chains and legions of production and improvement engineers necessary for manufacturing success – China will reap the lion's share of employment generation and economic growth.

The United States focuses too much on China's invention capability and its attempts to catch-up. While China's investment in R&D and promising new areas of research will likely result in some breakthroughs, the single-minded focus on China's novel product capabilities in competition with the United States misses the areas where China has already achieved competitive success. For the United States, the greatest challenge is how to capitalize on the job and broad-based wealth creation benefits of its novel product innovative capabilities. For the foreseeable future, China will not challenge the United States lead in novel-product innovation capabilities; the continued flow of top Chinese graduate students into American universities testifies to the strength of America's R&D capabilities in new technology creation and development. However, a combination of policies and practice resulted in the general decay of our capabilities in the development, commercialization, production and deployment of these technologies. As you know, many products, although invented in the United States, are never produced here.

The United States also needs to look closely at the second generation innovation capabilities in China because China studies the inventions and research in the United States very closely. It follows trends in technology and new enterprise formation in order to excel in future industries. China avoids much of the risk inherent in novel product innovation and receives many of the benefits utilizing such strategies. In the cases of new Internet-based technologies and services, Chinese competitors can emerge within a matter of weeks. It is important to note that this is not necessarily the result of IPR infringement or industrial espionage. Instead, Chinese entrepreneurs follow Western technology trends closely, looking for proven or promising technologies and business models to emulate and localize. Western venture capital firms in China, too, encourage would-be entrepreneurs Chinese entrepreneurs to form new ventures which imitate those recently launched in Silicon Valley and offer the guarantee of investment to sweeten the deal. Indeed, American VCs investing in China are one of the fastest and most successful routes of technology and business models transfer. China's approach to capitalizing on innovation affords it a great advantage in making use of technologies and business ideas developed elsewhere. With its massive market, production capabilities, political commitment to technology upgrading, and willingness to invest heavily in new technologies, China has an advantage over the

United States in capturing the broad-based returns from innovation.

This is not to say that Chinese firms will earn more money or greater profits than American innovators. Indeed, recent studies of Apple's profits reveal how profitable it can be to remain the world's leading novel-product innovator. However, in terms of other economic fruits of innovation, such as job creation – which arguably might have a much wider positive societal impact – China's producers afford more national benefit than Apple.

Conclusion

The lesson of China's innovation capabilities is that it has successfully developed a bottom-up innovation system. The global fragmentation of production provides many opportunities for Chinese firms and entrepreneurs to enter the market and has, for the first time, created real interdependencies between countries. While beneficial from an economic perspective, these interdependencies are politically volatile. When looking at China's innovation capabilities and the challenge it presents, great care must be taken not to exaggerate China's capabilities and what they mean for the world.

Although attempts have been and will continue to be made to mandate certain technologies or favor specific enterprises, these centrally directed initiatives are not China's strength or the true story of China's innovation prowess. Government procurement and technology standards have not been to-date successful means of promoting indigenous novel-product innovation. Rather, the source of China's strength is its ability to capitalize on, produce, commercialize and deploy new technologies rapidly and at scale. China's innovation system produces economic growth and job creation in excess of what would be expected given its comparatively low profit margins. Moreover, the global fragmentation of production and specialization of Chinese firms in these production and improvement niches creates a sustainable long-term advantage and competitive position for Chinese firms. Efforts at creating a new Silicon Valley or achieving technological supremacy through mandating patenting and academic publications, government procurement or technology standards will not yield major results for the foreseeable future. However, the United States must understand the competitive challenge of China in terms of its ability to capitalize on innovations elsewhere and so grasp the job creation benefits and engineering innovation opportunities from deploying new technologies at scale. China is not going to become the world's leading science and technology power in the next twenty years but it does not have to do so in order to be economically competitive and successful.

It might be that when dealing with the challenges China's innovation rise present us, we should paraphrase an insightful quote attributed to Charles Darwin: "It is not the strongest of the nations that survives, nor the most intelligent. It is the one that is most adaptable to change."

Thank you again for the opportunity to testify. I hope you will continue to think of me as a resource for your Commission and I welcome your questions.

PANEL I: QUESTION & ANSWER

HEARING CO-CHAIR GOODWIN: Thank you, gentlemen.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you both for being here.

Rob, good to see you again. You've been an active player on the policy scenes here in Washington, and I think over the last year or two, the attention to this set of issues that you and your organization focus on have been getting a lot more play and concern in government.

I'd like to ask a couple of related questions that cross both of your testimonies. Rob, you talked about your participation or advisory role to the Joint Dialogue, and Dr. Breznitz, you talked about a critical issue, of course, which is jobs, and how we see the intersection of innovation, the policies we have, and what the future is in terms of innovation.

Rob, what are we getting out of this Joint Dialogue? There are a lot of questions that have gone on about both NASA as well as OSTP's engagement with China. Many view that as one-sided. What are we getting out of it, and as we look forward--from both of you--how should we view this cooperation in terms of the benefits for job creation here in the U.S.?

DR. ATKINSON: Well, thank you, Commissioner Wessel.

A couple of things. One, I'm obviously not in any official capacity.

COMMISSIONER WESSEL: Understand.

DR. ATKINSON: I'm just advising as a private citizen. So I can't say in that context. And also there are two components of this dialogue view. One is the long-standing Science and Technology Cooperation Group, which I'm not an expert on ,and the other is the more recently formed U.S.-China Innovation Dialogue, which was formed out of the broader S&ED.

So what are we getting out of that? I think what we're getting out of that is the ability for both experts and U.S. government officials to be in a situation with the Chinese in an official way to get enough of government officials on their side together in one room for us to voice our concerns. That's how I see that, and from talking to some U.S. government officials, they find that of value because it's hard to sort of get everybody in a room and have them hear what it is we're concerned about.

I will say that in terms of the Experts Group that Dr. Simon and I are both a part of, I think one of the things that we're doing there--in fact, the last set of meetings we had last Tuesday in Beijing were really to set up a set of real deliverable projects that I hope will help educate the Chinese on the problems in their system and the advantages of our system, if you will.

There have been people who have said, well, why are we trying to help the Chinese develop a better innovation system? I really don't think that's what this is about. I think what this is about is to help them understand that the way for them to succeed is not to do indigenous innovation mercantilism, and that I think if we can move that ball down the field, even a bit, then we've made some progress.

COMMISSIONER WESSEL: But if you were to measure, again, you know, in this tight economy, when jobs is the number one issue, if you measure innovation through that lens, who is doing a better job?

DR. ATKINSON: Oh, I think the Chinese are doing a better job. I don't think

there's any doubt about that. As we assert in the book, we assert that one of the reasons for the financial collapse was the fact that we have had a very, very poor economy due to competitiveness challenges.

This was the first decade we've never created any jobs. We lost a third of our manufacturing employment in this decade as the report we just did said, greater than the rate in the Great Depression. And our assertion in there, which some dispute, but our assertion is that about 60 percent of those jobs were lost due to competitiveness challenges, not productivity growth, and a lot of that, as David Autor and his colleagues at MIT recently wrote, a big share of those jobs were lost to Chinese production. So I don't think we're succeeding in that process right now.

COMMISSIONER WESSEL: Dr. Breznitz, any comments?

DR. BREZNITZ: I think, as Robert said, it's clear that the Chinese are doing a better job, partly because we are not doing anything. There are jobs that we should lose to the Chinese. Some of them are not even the Foxconn, which we would consider illegal here, but, for example, the power supply of Apple--the white thing that you plug in--all the innovation that goes everywhere to make it smaller, better and more reliable is now done in China, partly because our engineers are not interested in those kinds of jobs. Yet on the other side it's extremely difficult to do many of those things here.

If you're a new start-up and want to have a production facility as part of your business plan, good luck finding financing in the United States.

COMMISSIONER WESSEL: Thank you.

HEARING CO-CHAIR GOODWIN: Commissioner Cleveland.

COMMISSIONER CLEVELAND: Wow. I'm really impressed by both of your testimonies. But just to play devil's advocate, I'm reading an article here that the staff gave us, by Richard Florida, and he says that he's done structural equation modeling assessing high-tech industries and universities, the creative class, and gauged the effect of these factors over time on economic innovation and growth in China, and he says the stock of human capital and their ability to generate high-tech industries and improve regional economic output does stand in contrast to the U.S. and other advanced nations, but it appears to have no effect whatsoever on innovation and economic growth.

And I'm wondering if this is tied in part to your testimony, Mr. Atkinson, on engineers, and you talk about 60 percent--where is it--its higher education system is focused on engineering; 30 percent of all first-time degrees are in engineering and 60 percent are science and engineering degrees.

Can you address, first of all, Mr. Florida's claim that there really isn't much effect? Is the target wrong? Is he focused on this first-generation innovation and not what you're talking about?

And then could you also talk about not all engineers being equal in what they're producing, and if that's a factor in innovation and economic growth?

DR. ATKINSON: Sure. Thank you, Commissioner Cleveland.

I have a couple of things. One is I've known Richard Florida for two decades, so I know his work pretty well. Richard is really focusing on a very narrow slice of innovation, sort of the creative, interesting, brand new, for example, the Facebook, Twitter kind of innovation which is both useful and important. It's an area of our strength, but it's a very modest slice of the overall innovation pie.

And I think for Richard to say that, I mean if you look at some of the

statistics I had in my testimony--China's trade balance in high technology goods for example--it went from zero a decade ago to 155 billion. Their global share of high-tech manufacturing value-added went from three percent to 19 percent. Machine tool production is 35 percent of global machine tool production. Machine tools are pretty innovative. Furthermore, circuit board production is 31 percent of that.

Now I don't really care whether we call that innovative or not. I call that pretty good technology-based production and most of those cases, I would assume--I don't have any evidence that they've innovated in an original way in any of those areas--that they are able to capture the production of that, which is an important component.

With regard to your second question about engineers, I mean I will admit that 30 years ago, the Soviet Union produced more engineers than the U.S., and it didn't mean anything because (a) they weren't very good; and (b) the Soviet system really wasn't designed to do very much in this space.

I think that's different in China. Certainly, not all their engineers are at the same caliber of our engineers, but there are a couple things I would like to point out. When I've talked to American companies regarding this subject, they have been somewhat impressed with some of the engineering talent they get over there. They're not all subpar; secondly, the Chinese are also working very hard to continue to improve their engineering graduate and undergraduate education.

So I don't think we can assume that they're going to be like the Soviet Union, which is kind of a sclerotic, not-very-good system. They're working hard to improve that.

COMMISSIONER CLEVELAND: And their engineers are educated here, which is a factor. There's a very good book out called Surpassing Shanghai, which is focused on educational systems, and they train their engineers here, and it focuses on the fact that they go back there and make a quarter of the salary that our engineers are making but essentially producing just as well.

Dr. Breznitz, do you have any comments on the question of quality of--

DR. BREZNITZ: Yes, Sure. So first of all, while I like Richard Florida, I, again, think that he just doesn't get it when it gets to the effect of innovation, economic growth and sustained economic growth, which is what we care about.

I would also say that if you look at the certain slice of Chinese companies, I mentioned Huawei before, but let's also talk about ZTE, Tencent, and many other small ones, you already see them improving the products and coming up with their own products and actually being better, according to our companies that ask to remain anonymous, at current generation technology.

In regards to engineers, we should not be surprised. Remember, they basically killed all their engineers and scientists not so long ago--Chairman Mao. And what they managed to do in basically 20 years is utterly impressive so we can just imagine what they will do in 20 years, even if they don't improve that much.

And those engineers, not even those that come here, are willing and trained to work in areas where we don't train them anymore, like coal, like real old electric engineering, and if we want to build a small grid or an alternative energy or anything else, those engineers exist in China. They don't exist here.

COMMISSIONER CLEVELAND: Is there anything that either of you could suggest that we read on what the nature is of the graduates from engineering schools?

Have there been any studies done as to what this cohort looks like?

DR. ATKINSON: I don't have that. Denis Simon may. You might ask Denis, but I don't.

COMMISSIONER CLEVELAND: All right. Thanks.

HEARING CO-CHAIR GOODWIN: Commissioner D'Amato.

COMMISSIONER D'AMATO: Thank you very much, Mr. Chairman, and I want to thank you both for your testimony.

It's very interesting testimony, and it's interesting to contemplate the way you're describing what might be, if not a new model, the paucity of the old model to reflect what is happening vis-a-vis our economy and the Chinese economy in terms of innovation and the fragmentation of the global production chain and the effect of innovation on that in that just because you invent something, not everything happy occurs after that in terms of production and the trade numbers that will all flow from that, and you won. So this is a new way of thinking, a new model. I think it's very important for us to understand that.

The question is what do we do about it in terms of if we cannot convince the Chinese to change their behavior in terms of the way that they handle IP and the forced technology flows and mercantilism across the board as we've seen it over the years? What is it that we do now?

I do note, Dr. Atkinson, that you have talked about the need to, quote, "band together," band together with other free nations to use the power of exclusion and pressure to compel China to change, create a new free trade zone--presumably the Trans-Pacific Partnership would be that genre--and to use certain kinds of numbers and goals to compel the Chinese to move in the direction of less mercantilist behavior.

I understand that and it sounds good to me, but what does that do in terms of our commitments to our international trade obligations, standards, the rules of the game, and WTO rules? Do we just say that we're going to have to deal with this problem as it exists and do whatever we need to?

Also, Dr. Breznitz, you talk about the real challenge of meeting the question of commercialization of these various production technologies along the vertical chain at all these stages where they can behave in a mercantilist fashion and grab the market, as they do from us.

The question we have, of course, we'd like to make some recommendations what to do about this. What is it that the national policy should be given this new model and understanding of this new model? What is it? How do we address it properly to defend and promote our national interests?

DR. ATKINSON: Well, thank you, Commissioner D'Amato.

I have a couple of things. One is I look at this essentially as a monopsonistic market. They are so big. If some small country did this, multinationals would basically just write them off. Say fine, you're going to play by these kinds of rules, we just won't invest here.

They can't do that in China, and China knows it, and they play off companies against each other. They play off countries against each other. And I think the only answer to monopsony is monopoly, and what I mean by that is that if we and the Europeans and the Japanese collaborate and say enough is enough, and you hear that from European CEOs, and you hear that from Japanese CEOs, and you hear that from officials at METI and various Europeans who are really beginning to get frustrated,

and I would argue we in the United States need to assert global leadership and bring everybody together to create this new trading pressure.

One thing I would do besides the TPP, which we've advocated before, is build a transatlantic partnership where we really bring the Europeans and the Americans together and maybe the Commonwealth countries to basically say we're going to trade together, and we're going to exclude you, China, unless you participate.

A couple other things I would do is try to get forced JVs in the WTO, and there is really no reason why we should allow forced JVs to the extent we do. Every country has some limitation carve-out of areas where you have to do JVs, like in cultural industries or things like that, but the extent of the Chinese JV requirements, to me, are outside the bounds of trade, and they're not actionable, and I think we should be pushing for them to just say you can't do that.

And, lastly, an idea that's a little bit outside the box, but I'll throw it out there, is I think we should begin to think about reforming our antitrust rules akin to what we did in '84 where we had the Collaborative R&D Act, which was an antitrust exemption for pre-competitive R&D.

I think what we need is an antitrust exemption for U.S. companies, and ideally European and Japanese companies, to have a collaboration or, if you will, consortia around tech transfer to China. What China does is they play off companies against each other. We see that now with Boeing and Airbus, you know. You give us your technology, you give us a little more, you get more of the market.

Neither Airbus nor Boeing want to do that, and if they could band together and say here's what we're going to do, and only that much, I think then they would have more leverage over these Chinese demands.

COMMISSIONER D'AMATO: Thank you.

DR. BREZNITZ: Well, I would wish you luck to get the EU to do anything, but I think there's a lot that we can do. If we realize the fragmentation of production, we should also start to realize that we no longer talk about the company. So you talk about Apple and everything, and everybody thinks it's Apple, but if you look at how they actually manage to produce, including the innovation that goes to an iPad, and make the product, you're talking about the whole network of companies.

What we should start to think, therefore, is what kind of networks of companies in the U.S. can produce great innovations, but also good jobs, to a vastly larger degree than what we have now, and it's not rocket science. I mean the Chinese have immediately realized that we have a lot of start-ups in solar panels, and yet nobody here is willing to produce production facilities, and they grabbed it, and it's a classic market failure, where for private companies it doesn't make sense. The financial system in the United States is not built anymore or any longer to do that, and these are areas where we should think about it, especially since many of those facilities are critical for our securities.

COMMISSIONER D'AMATO: Thank you.

HEARING CO-CHAIR GOODWIN: Chairman Shea.

CHAIRMAN SHEA: Thank you. Thank you, both, for being here. I really enjoyed your testimony.

I think in our 2010 report, we did recommend an antitrust exemption for collaborative efforts to respond to forced technology transfers so I think we're on the same wavelength there.

Everybody loves innovation. Americans are known for innovation. We celebrate Steve Jobs. We celebrate Facebook and Apple and Twitter, Groupon. At least my wife loves Groupon. But do we place too much emphasis on innovation, on novel breakthrough innovation as a job creating engine? Do policymakers in the United States place too much emphasis on that?

And could you describe for me--we heard some great testimony a couple years ago from a guy named Willy Shih up at Harvard Business School. I think Andy Grove has written about this as well, that there is a lot of innovation around the manufacturing process, and when you lose manufacturing, you lose the opportunity to innovate. Perhaps it's the second-generation process, incremental innovation, Dr. Breznitz, that you referred to.

So help me understand that. Is there a lot of innovation around the manufacturing process, that when we lose pieces of manufacturing, we're also losing the opportunity to innovate?

DR. BREZNITZ: So let me just take you back in American history. Henry Ford invented the Model T. If we stop innovation in the car industry at the Model T, I'm sure that America wouldn't be what it is today, and your wife would not be that happy with the car she would buy.

So many of the industries where we don't even think that there's innovation, like cars, we sort of take it for, we assume, there's constant innovation all the time both in the car, material science, ICT. Those are engine technologies. And those are innovations that at the end of the day make the greatest impact on economic growth.

It's not the fact that we invent the internal combustion engine. It is actually how we make it into work, into something that people will buy, use to produce other stuff, and preferably more reliable, better and cheaper, constantly.

We used to be really, really good in that. As a matter of fact, we used to excel in that, and we taught the Japanese how to excel in that after World War II. So, no, the problem is not that we are celebrating novel product innovation too much, but we somehow assume that we're still in a world where if you innovate, all the rest will happen within your borders, and this is just not true any longer.

And what we don't have that much anymore is a system that allows us to grab at least a better share of those activities. We will never gain everything anymore, nor should we hope to, but certainly we can do a lot better, and I think that it's a worrying sign when I look at optoelectronics, for example, and I look at the most advanced design of optoelectronics, and I find out that some companies are dumbing up their chips in order to produce them in China because they cannot build a production facility in the U.S., and that's something we should think about; how can we fix that?

And I would also say that we probably should be slightly tougher with China with or without the EU on which I hope never to depend upon.

[Laughter.]

CHAIRMAN SHEA: Mr. Atkinson.

DR. ATKINSON: Well, Danny I think said it all, but I think one component--I would agree with him. It's not like we're doing too much science-based innovation, but if you think about what is the real strength of the U.S. system, it's science-based innovation. Look at the strength of the German system. It's engineering-based innovation. The Germans have significantly outperformed us in manufacturing in terms

of value-added growth, jobs, and global trade.

Why have they done that? Because they essentially have a very deep engineering culture. They produce more engineers as a share. They have the system of Fraunhofer Institutes. They do wonderful apprenticeship programs so they train front-line workers in deep technical skills.

I would argue that our challenge, what we need to do as a country, is really build back up our engineering culture as a country, and that means specific policies around--we have a new report that will be coming out in about a month or so on U.S. manufacturing strategy, and one idea we have in there is to have a challenge grant program to create 15 or so national manufacturing universities, not that they wouldn't continue to teach English or anything, but they really, really focus well on manufacturing.

They would train manufacturing engineers who could go out and work well with industry; they'd work collaboratively with industry. We don't really do that very systemically, and the Germans do.

CHAIRMAN SHEA: Thank you.

HEARING CO-CHAIR GOODWIN: Commissioner Slane.

COMMISSIONER SLANE: Thank you. Great, great testimony.

I used to derive a lot of comfort by reading economists here who say that the Chinese cannot innovate, and therefore they will reach a wall, and their GDP and their standard of living will just stop at that point.

And as you have described today, it's a lot more complicated than that, and really if I had a choice between innovating something or taking that innovation and modifying it, I'm much better off modifying it, especially if I can steal it or if I can, if I have no impediments to modifying it.

And I think it's something that we need to bring to the attention of the American public, and certainly of Congress, because when you look at the Chinese culture and their education and the SOEs and creative destruction and all these issues, they can innovate, and it may take them 20 or 30 years to overcome all of these things, but that doesn't stop them from destroying us economically.

And the thrust of my question-- Commissioner D'Amato has already asked it--is how do we stop this from happening? But I think you both have really answered that, and the thing that worries me is that they are coming, they're coming here, and they're going to open up their factories here in the United States, and so we've spent a fortune on doing all the R&D, and now they are taking that and modifying it. So the hole just gets deeper.

DR. ATKINSON: I would agree with that, and I think--this is one of those problems where I think the problem is not so much with the--I'm agreeing with you, by the way, not so much the problem of the American public not understanding. It's really the Washington elites, I think, that are the problem. I think there are way too many who have this inherently deeply-held view that we just don't have to worry because the Chinese can't innovate or, as you said, the new theory that's popular in Washington now is they're going to hit the wall for a variety of reasons. Just let's sit back, relax, they're going to hit the wall, and they'll collapse. We'll all be fine.

And they will hit the wall eventually. They will hit the wall essentially when they get to the stage of Japan, which is long time from now. So Japan has hit the wall in some sense. Japan's productivity is not--actually, believe it or not, their

productivity actually was higher this decade than U.S. productivity. Very interesting fact that very few people know.

But Japan really has sort of hit the wall on being an export-led economy. They don't have high levels of domestic innovation. But you can go a long, long time before you get to that wall, and I think the Chinese can go 40 or 50 years before they get to that wall, and in the process, as you said, I think do a lot of damage.

I think the other big mistake a lot of people in Washington make is they have this view that intellectual property theft and a weak IP system, which the Chinese certainly have, is detrimental for innovation. I think that's true, but it's really only true when you get to a certain point. When you steal enough and then you get a lot, theft is a good strategy. It's only when you get to a certain point in your development that theft becomes a suboptimal strategy, and then you want to protect because you've got a lot of IP that you can generate yourself. Then you want a protection system.

So I think in the long run or maybe even the medium run, the Chinese weak IP system is a detriment to them, but in the short-run, I think it works quite well for them. They are gaining.

One of the things the Chinese need to do--I mean in their goals, their whole plan, that to me is about a 40 or 50 year plan if you were to do it sort of naturally. In other words, you build up your capabilities in your firms; you graduate more engineers; you build better universities. That's a 40 or 50 year process to get to the goal they want.

They want to shrink that to about ten to 15 years. The only way to do that is to take other people's technology and incorporate and integrate it into what they're doing, and that's essentially what they're planning, what their whole strategy is all about.

DR. BREZNITZ: I will just say that if the Chinese actually move manufacturing here, at least they will save us from ourselves, but I would say that, first, with hitting the wall, the same thing was said about South Korea, and last that I've checked, South Korea is still going strong. So I don't expect everyone to hit the same wall that Japan hit.

We also were basically with China and South Korea in the last century, and we did quite well for a hundred years. So we should not rely on China failing.

I'm not sure that China as a state has this grand strategy where they actually understand everything that they're doing because the failures of the central government are unbelievable. But they have--(a) they have goals; (b) they have the will and the power to go and do something about those goals. They have extremely capable officials in the provincial and townships, which are doing everything in their power to make this system work, sometimes against the wishes of the central government, and we don't have that much.

And we rely on things to somehow happen. I think it is time that we wake up and smell the jasmine or the ginger or whatever you want to call it because it's coming.

HEARING CO-CHAIR GOODWIN: Commissioner Reinsch.

VICE CHAIRMAN REINSCH: Thank you.

I'm sorry to have missed your testimony so I hope I'm not going over old ground, but, Dr. Breznitz, I wanted to ask both of you to elaborate on a couple of comments you made and responses about financing and the difficulty of obtaining

financing in various parts of the process.

We seem, I would hypothesize that we seem to do a pretty good job at basic research, but there are, in my view anyway, gaps beyond that. Could you, each of you, talk a little bit about where those gaps are and what the failures are in the private venture capital market that we need to tackle?

DR. BREZNITZ: So I think we're best and still the best in basic research. We are still also, and we should give that to ourselves, the best place in the world if you have an idea and you want to make it into a new product or a new service. The second, and by far second, is Israel, which I just visited, and here you sort of end.

What we are not good at is once any of those ideas actually involve production, manufacturing or even testing of production, which costs a lot of money, ties up finance for many years. It's asset heavy, and it's basically against everything that VCs want because VCs at the end of the day want to maintain their real business model, which is to buy cheap and sell high, preferably within two years.

Therefore, any business plan that is actually long-term, so clean tech, to some degree, bio, or involved production, which is hundreds or maybe billions of dollars, you should not expect VCs to do that.

The other problem is that we no longer have vehicles, financial vehicles, that know how to do that. So another thing that Germany has, and we used to have, any of you remember if you had a Visa card many years ago, it was Chemical Bank, now it's Chase Bank. It was called Chemical Bank for a reason: they were in the chemical industry.

Germany still has them. Even Italy has specific banks for specific industries. We don't have any financial vehicles, organizations, whatever you want to call them, that know how to invest in production, the business model is investment in production. Partly, it's also because of how we incentivize finance. And we are good--it allows us to become the best in VCs. VCs did not emerge from error. They emerged from regulations, specific regulations which we enacted.

We should maybe think about how to incentivize finance to invest in production in the U.S. because the same financial institutions are actually investing a lot in production facilities, just outside the U.S.

VICE CHAIRMAN REINSCH: Rob.

DR. ATKINSON: So I think one helpful sort of mental image to think about the U.S. economy is it's a box. It's moving along on a time scale, and on the front end, we're adding new thing to the front all the time--new innovations, new products, new services, new business models, and on the back end we're losing stuff. This is sort of the old regional theory of product cycle theory, that we innovate, and then as things get mature, they shed and they go to low cost regions.

What the Chinese are doing—there are a couple of things. They're trying to get on the front of that, but they're also trying to speed up the shedding, if you can, as fast as possible. So we need to slow down that back-end loss to some extent. I mean there's certain stuff we're just going to lose because we shouldn't be doing it, like T-shirt production.

But the other thing we need to do is we need to speed up that front-end process. So this goes to, Chairman Reinsch, your point. We don't do anywhere near as good a job as we should. If you look at venture capital funding, we invest essentially--before the recession--about twice as much VC investment as we did in the mid-1990s.

But we have half as much in what's called zero and first-stage deals.

So it's really declined by 75 percent when you think about it. In other words, VC companies have moved up into later stage deals. They've moved up into bigger deals. So we don't do as good a job on the early stage VC financing as we used to.

The second problem we have is we have vast variation in our ability of universities and federal laboratories to be technological commercializers. We've got some really great institutions, like Caltech, MIT, Stanford, but there are a lot of other institutions that have strong capabilities and weak performance.

And we don't have a system that rewards them or penalizes them. You just keep getting money no matter what, and I think what we need to do is put in place a real system of incentives so that we live up to our real performance capability, which I think we're not living up to right now.

VICE CHAIRMAN REINSCH: Thank you.

HEARING CO-CHAIR GOODWIN: Commissioner Bartholomew.

COMMISSIONER BARTHOLOMEW: Thanks very much, and thank you both, gentlemen. This is very interesting testimony.

I want to explore a little bit, though, the tension between innovation and jobs because we have a tendency to talk about innovation as invention and lots of jobs are going to flow from it, but if you look at innovation within the manufacturing sector, creating efficiencies, I'm thinking about robotics in particular, you lose jobs. You don't gain jobs.

And I'm just trying to think about what that means in China, for example, as it tries to move up the value-added chain. China has an enormous population. Granted there are some demographic changes and some tensions that are going to be happening fairly quickly. But if you move up that value-added chain in a way that is competitive, it means you need to be able to do more with less. And how is that going to work?

DR. ATKINSON: Thank you for asking that because that's a question we have thought a lot about and written a lot about, and I just would say I think there is a fairly broad-based misunderstanding of this key point.

First of all, at the macro level, the evidence is very, very clear, at least in developed countries, the evidence is crystal clear that high rates of productivity at the economy-wide level are positively associated with lower rates of unemployment.

So if you think about the U.S., we had low rates of productivity growth in the '70s and '80s and high unemployment, and it switched in '95. Now, the recession, it's a little different. So the evidence is very, very clear. What you can have is you can have high rates of productivity in some industries and job loss there, agriculture being a great example of that.

But there is a recent study by William Nordhaus at Yale, which we have cited, and I can get it for you. Nordhaus looked at the relationship between productivity in U.S. manufacturing and output growth, job growth, and he found that they were actually positively correlated through, up to 2002, I believe, and Brookings recently did a study that extended that out later, and they found still there was a positive correlation.

I think for China, to me, the major mistake China is making, and if I could--I've said this to Chinese officials many, many times; they look at me like I'm crazy--the

major mistake the Chinese are making is they are trying to grow their economy through a very small slice of moving up the value chain in a very small number of industries.

So if they achieve their goals of the strategic and emerging industries, we've estimated that what they get is 14 months of economic growth. In other words, they've added--essentially take 14 months of economic growth, throw that on over the next 20, next ten years, that's all they've gotten.

And what the Chinese don't want to do, and the Japanese don't want to do this either, the way you grow an economy is through broad-based productivity across all of your industries, and if you go to--you've been to China--you see this--you see it with your own eyes--the vast overmanning and vast inefficiencies in many, many Chinese sectors, banking being a great example, retail, trade, government services. That's how the Chinese are going to get rich.

And what they don't understand or maybe don't believe is that somehow if they do that, they'll say we're not going to create enough jobs, and at the macro level, evidence just simply disputes that. You can create a lot of jobs with high productivity if you have the right macro fiscal and monetary policies.

COMMISSIONER BARTHOLOMEW: Are those jobs for the same people though? I mean are they in the same sectors, this increased employment that goes with the increase in productivity? Are those--

DR. ATKINSON: Not necessarily.

COMMISSIONER BARTHOLOMEW: Yeah.

DR. ATKINSON: I mean clearly the Chinese are losing people on the farm as they raise productivity. I would argue they should do that even much faster. Not necessarily, but I think, again, I think if you have the right policies, both at the macro level and at the structural level to make sure that workers can get retraining and you have flexible labor market policies, I would assert there is no inherent reason why in a country like China, high productivity means that they won't create enough jobs. I just don't buy that argument they make.

DR. BREZNITZ: I'll just add that the one thing that I think the Chinese should worry about maybe is an opportunity for us. If you look at high tech exports from China, I mean over 95 percent, maybe even over 98 or 99 percent, is just ICT hardware. They have now in the last three or four or five years tried to make it appear that it's not by putting electro-optics out of ICT hardware, but it's still ICT hardware.

So most of their gain in high tech exports is just one really small slice of industry, where we are actually really strong in innovation, so we might, if you want to have recommendations, think very strongly about ICT and ICT manufacturing.

There China might have a moment of reckoning. I think it is not going to happen any time soon because many of the products they produce actually necessitate a lot of human beings. So if you are the first to produce an iPhone, and you don't even know how to put the glass screen, you would really want human beings to play with. It's when they will systemize everything where they'll have a lot more robotics and a lot of more interesting questions to deal with.

COMMISSIONER BARTHOLOMEW: Just one comment, which is that I mean our manufacturing sector has become so efficient and so lean. It's interesting to think about all of them, and we've focused on this, the different advantages that the Chinese government provides for its companies, that they can beat our guys, even with all of the inefficiencies that they have in their systems, and I'm taking labor costs out of that.

But I mean, you just go into an American manufacturing plant these days, and it's amazingly efficient what's going on. So thanks.

DR. ATKINSON: If I could just quickly respond. That's true, but if you, a recent report we did on manufacturing, we looked at productivity growth in the last decade. U.S. manufacturing, if you, I think, measure it right, actually did not perform as well as many of our competitors. Japanese productivity and manufacturing actually went up much faster than U.S. manufacturing productivity. Swedish manufacturing productivity. South Korean.

So you're right in the sense that we have advantages, but I think Danny has said this as well, we need to do a lot more to get our manufacturing productivity better, including things like funding the Manufacturing Extension Partnership Program. We still have challenges, but that's the only way where we're really going to fundamentally be able to beat the Chinese in manufacturing.

COMMISSIONER BARTHOLOMEW: Thank you.

HEARING CO-CHAIR GOODWIN: Thank you, gentlemen, again, for sharing your insight. I'd like to flip this around a little bit and talk about it through the lens of economic development here in the United States.

I come from West Virginia where it's a constant challenge to try to maintain manufacturing jobs and, like many states across the country, have faced significant losses over the past several years.

Dr. Breznitz, as you said, we care about the effect of innovation in terms of job creation and sustained economic growth. So I'm interested in hearing what aspect, if any, of China's innovation model could be applied here by state policymakers, legislators, and economic development professionals in states like West Virginia to attract and retain high-paying jobs?

I don't believe I've heard anyone say that we should start limiting the amount of money spent and invested in first-generation breakthrough product research and development? But with finite resources in the public coffers, could that money be better spent by economic development agencies in West Virginia on encouraging second-generation and production innovation, and is that even realistic to talk about in those terms given some of the barriers to capital and financing that you discussed?

DR. BREZNITZ: So I would say that it's not necessarily the same money that you invest in first innovation that could go to second-generation innovation. That would probably not be the wisest because this is where our real strength is, and in order to have a second generation and excel in it, you have to be the best in the world in first generation because by now we are not the best in second generation.

We should start thinking, and maybe if you want to talk about West Virginia or rural Georgia, where I'm visiting more often, we should start thinking about what locales and townships in China are doing, and they're trying to figure out how to help a vast majority of really small and sometimes medium enterprises come and control a niche of a market, working together. So they don't even think about one company. They think about how all those companies can constantly innovate in second-generation innovation and together come up with a product, and for that, we probably need to think more about issues of shared assets.

I'll give you an example from high tech. If you're a biotech company, and you want to have access to the best instrumentation, you can come to a university next to you, and you'll have access to everything to basically run your experiments.

If you're a small manufacturing company, and you want to start to play with innovation, which by far are more expensive equipment than what you have, you just don't have that equivalent. And a real question is why you don't have that equivalent, and how can we think about having those kinds of shared assets? And those are shared assets in testing, shared assets in playing with innovation, shared assets in manufacturing. It might very well be that you have a lot of small and medium-sized enterprises in metal bashing industry in western Virginia, but you don't have an assembler there where they can all basically put their production together, and as they take over production, which is basically the business model of TSMC, Taiwanese companies that now control all the fabrication of IC chips, become profitable. We just don't have those.

And the other thing that worries me a lot is I worked with Sue Helper, who is now in the Office of Science advising the President, and what we found in the automobile industry is that the small and medium-sized enterprises were much happier to work with the Japanese and German on anything about risk and innovation than they were with American car manufacturers because they couldn't trust the American car manufacturer to not switch out as soon as somebody offered the lower price.

If you want to excel in second-generation innovation, you have to build trust between your suppliers. You have to work at it together. Part of it is something that government, be it federal or local, can do. You can also create institutions that allow this. Part of it is just laws like antitrust, and part of it is trying to educate industry, American industry, how to work together if they want to survive the challenge of other countries that are working together sometimes by government fiat.

HEARING CO-CHAIR GOODWIN: Dr. Atkinson.

DR. ATKINSON: Yeah. Just quickly because there's not much time. I think there are many, many things states can do. Just again to cite this report we have coming out in about four weeks, we have a section on each of the recommendation areas for what states can do in areas like technology and talent and tax.

But I think one thing states can do is they can reorganize their workforce training systems much more around clusters or sectors. You've seen this in, I can give you a good example, in Pennsylvania, they have an industry-led training alliance up in near Erie. I believe, I could be wrong, but I believe it's around foundry technology, but they've got the companies together. They collaborate. They share apprenticeship programs. They work with the community colleges, and they design curriculum that's going to be directly related to the needs of that particular regional industry. And I think that's a much more useful approach than what we do in training a lot today.

The second thing I think we could do, that states could do, is they could work much more effectively of getting their industries to be real partners with industry--getting their universities to be partners with industry.

We have a program at the national level called the Engineering Research Center program that's been set up in the '80s to meet the Japanese and German challenge, and it's a program that funds these centers, and frankly it's not as effective as it should be because they don't require any industry funding.

In Germany, these centers have to have two-thirds of their money from industry so there's real industry buy-in. These centers have to be cooperative and responsive to industry. Here these ERCs, they don't have to be, and oftentimes they aren't.

One last idea, a lot of countries now, just in the last few years, and now actually this province of Alberta created a new program called Innovation Vouchers, and rather than take and increase funding for universities, they've taken that money and they've given small vouchers of around $20,000 equivalency to small companies to go and use that at a university, and what the response has been in these countries that have done it, the universities become much more market friendly, much more oriented to say, you know, they almost market their services.

They all go out of their way to be accessible to small companies to solve technical problems, as Danny was alluding to in China.

So I think we need more institutional kinds of innovations like that, and states are wonderfully positioned to lead that.

HEARING CO-CHAIR GOODWIN: Thank you.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you, Mr. Chairman. Thank both of our co-chairmen for putting together an excellent panel and, of course, to the staff for helping with that. And this is one of those panels that probably we could spend all day just going back and forth.

Let me go to an issue that I think gets to the core, and Dr. Breznitz, you talked about the finance issue, and the issue of TPP came up, et cetera. TPP is expected to have a chapter on supply chain integrity. When you look at corporate finance, they're guided by IRR and ROIC, internal rate of returns, return on invested capital, they don't really care where the investments are made. They may have a slight preference if their corporate office is here or they have a huge presence, but the fact is they're guided by investment returns.

The TPP, which some view as a containment strategy for China, may also simply be a desire to disperse these supply chains to prefer some Asian countries or those around China rather than China, and to try and move supply chains in that direction, and that has some benefit. But it doesn't necessarily result in jobs here, nor does it necessarily, because this is the core of our issue, enhance innovation here.

Other countries, China, Malaysia, Singapore, many others, have industrial strategies, and I know that's a bad word here in the U.S., and both of you have talked about expanding skills, et cetera. We really have to go, though, with the core financial structure of the returns that are available to companies to be able to take what may be basic research out of our federally funded or universities, et cetera, and be able to bring it out into the production, into the supply chains.

How do we do that without getting into a subsidy war with our competitors or is that simply what we're talking about here? We're all going to try and drive down costs from a governmental level. I'm not adverse to that although I don't know where we come up with the money now. We're talking about innovation, we're talking about all these various issues, but at the end of the day, it's really just about money; isn't it?

DR. ATKINSON: I don't think it's all about money. You hear, for example, the National Association of Manufacturers assert that they have their 20 percent cost difference, and if we could just get that fixed, everything would be good.

COMMISSIONER WESSEL: You said cost.

DR. ATKINSON: Pardon me?

COMMISSIONER WESSEL: You just said cost.

DR. ATKINSON: Right.

COMMISSIONER WESSEL: Which is money.

DR. ATKINSON: Right. No, and I'm--

COMMISSIONER WESSEL: Okay.

DR. ATKINSON: --now going to say why I don't think that's enough.

COMMISSIONER WESSEL: Okay. All right.

[Laughter.]

DR. ATKINSON: First of all, besides the fact they don't include labor, and German labor costs are 45 percent higher in manufacturing than U.S., in dollar denominated terms. So cost is a factor, and don't get me wrong, I think it's important. And, for example, I recently testified at Senate Finance on this issue. We have--there's a new study, an economist who published in the National Bureau of Economic Research, who looked at the effective tax rate, effective, not statutory, in manufacturing in 20 countries. We were number two next to Japan, but I believe now with the Japanese lower rate that we really are number one.

So I think we have to do something on that level, and what we've proposed is I think we need a grand bargain with U.S. companies to say if you invest in the building blocks in America, which is R&D, training your workers and investing in new machinery and equipment, you will get a much lower tax rate.

That's to me the model. That would lower, that would provide an incentive. It would also lower effective rates, make them more competitive.

But even if we do that, I don't think that's enough. I think we've got to build a real innovation system in the U.S. around technology for manufacturers. That's why I'm very supportive of the administration's proposal, this NNMI proposal, National Network of Manufacturing Institutes.

I think, so I think we've got to have both. We've got to have a technology strategy, and we also have to get the cost side of it under control.

COMMISSIONER WESSEL: Thank you.

DR. BREZNITZ: So, no, I agree completely with Rob. It's not only cost because if it was only cost, why are we losing bio-pharma jobs to Denmark and Switzerland, which are not exactly the cheapest place on earth?

We can do a lot about the costs, but what I think we are not doing that well is to understand where are our strengths and how to work on them. We assume that industry knows, but most industry is, as you said, focused on their profit. They should not solve that problem. The role of government is to think for the public or to at least care for the public, and here we might want to learn actually from a country like Israel, which had the exact same problem.

You had the huge growth of innovation, actually huge inequalities in production, productivity levels going down in the business sectors. And what they figured out is that a lot of manufacturing actually have no access to the new knowledge. So if you want to have industry in West Virginia, you should not assume that the industry even knows what are the new technologies, and you should not assume that the students and labor who know that will ever talk to industry.

So they developed a program of basically internships in traditional industries where, and thankfully for the recession, we might have availability of good graduate students, part of your training for a master's or even a Ph.D. is working with small manufacturing, and there you train that manufacturer to think and “routinize” innovation. You train the students to actually work with industries, and sometimes it

works; sometimes it doesn't. But at least you allow the diffusion of knowledge, which I think is a huge problem in the U.S., especially when you don't have what you call about the whole supply chain.

Once you lose a supply chain, then you have holes. You also assume that you have holes in the diffusion of knowledge and diffusion of skills. And I think that's where states probably can do a lot more than federal government. States and even townships know what industries they have, know what skills they have.

They can probably work with the federal government to then understand what holes they have and how to fix them. So it's training, it's sometimes finance, maybe even just allowing pooling of resources, but it's not just money. If it was just money, then let me remind all of us that American corporations sit on the biggest war chest of dollars that they ever had, and yet they don't invest in the U.S.

COMMISSIONER WESSEL: Thank you.

HEARING CO-CHAIR GOODWIN: Chairman Shea.

CHAIRMAN SHEA: Just one question for Dr. Atkinson and then one question for Dr. Breznitz.

I've heard, Dr. Atkinson, some very smart people say that young Americans enter college wanting to go into the sciences, want to be engineers, and they're very capable, they're capable of doing that, but the financial incentives are skewed to financial services, and I've experienced that in my own life. I lived down the hall from a young guy who represented the United States in the Math Olympiad. He was a brilliant guy, but he went to Wall Street.

So is that--I don't know what the truth is, but I've heard this statement made, and I'd love to hear your response to it.

But let me, and then Dr. Breznitz, you obviously have spent some time reading Alice and Wonderland, and I was wondering if you could explain the metaphor behind Run of the Red Queen?

And in your book, you talk a lot about structured uncertainty, that Chinese innovation takes place in the context of structured uncertainty. If you could explain what you mean by that that would be great?

DR. ATKINSON: So we, my colleague Merrilea Mayo and I, wrote a report about a year-and-a-half ago on STEM education in the U.S. called Refueling the Innovation Economy, and we actually analyzed the cause, tried to analyze the cause of the STEM shortage. I think you're not mistaken, but I don't think that's the only or even perhaps major factor.

Engineering salaries and science salaries, they're actually still pretty good. They're about the third-highest occupation wage in the country. That's not to say that some people don't get even higher wages in finance.

The deeper problem, at least according to our analysis, is we could solve the STEM education problem overnight if we just eliminated what are called switch-outs. There are a lot of kids who go into college and they want to major in engineering or science, and about 35, 40 percent of them switch out in the first year, and it's pretty clear why they do it, and it's pretty clear what the answer is. There is just no incentive for universities to fix it.

One of the problems is that the average grade of a science or engineering course is almost a full grade lower than a social science course, and I would assert that's not because engineers are stupid. It's because they just grade harder.

A second big factor is that they don't give engineers and scientists any real experience, any real interesting courses or real hands-on experience until they're juniors or seniors, and what's interesting is the Howard Hughes Medical Institute now has a new program they set up about a year ago, where they take freshman, and in the summer of their freshman year, they put them in laboratories with real, you know, university medical centers and things like that, and the evidence of those kinds of programs are really, really powerful.

It turns out that you get a bigger retention rate because kids see, oh, yeah, now I've got to slog through the math. I know what I'm getting if I can stay with it. So we know how to do it. We just don't have the incentives in place to do it.

CHAIRMAN SHEA: Thank you.

DR. BREZNITZ: I'll just add that this is a real problem in Georgia Tech. We grade very hard, and you know 2.78 might be very high in Georgia Tech, but then those guys go--and girls--go out. They will never find a graduate degree anywhere. But if they switch to social science, even to very high-rated universities, they are basically guaranteed the 4. So that's a problem.

Now, the Run of the Red Queen, in the book, through the mirror glass and what Alice finds is she meets the Red Queen, which is actually the black queen of chess, you know, culture between England and the U.S. and then a century. And that queen starts to run with her because Alice wants to reach somewhere, and they run really, really, really fast for a long period of time, and they stop, and then Alice sees that she is exactly in the same place.

And she asks the queen, what is happening, and the queen says what do you mean? And she said, well, in my country if you ran really fast for a long period of time, you will reach somewhere, and the queen looked at her and said you live in a very slow country.

[Laughter.]

DR. BREZNITZ: So that's what China does. China runs as fast as it can on the technological edge to be there and actually offer services that we may no longer offer. So when Apple wanted to create the iPhone, as we all know, thanks to the New York Times, it was the Chinese who knew how to produce. But what they don't do is challenge a border. They stay on the cusp, always willing to enter any niche that is deemed profitable. They don't move the edge, and this is a viable strategy in a world of fragmented production.

And that is why we said in the book that this is, it's not what the Chinese central government, by the way, wants to happen, but this is a strategy that developed; it's a sustainable strategy. I don't see China hitting the wall in the next 15 years even if they don't do any novel innovation, just by following the Run of the Red Queen logic.

And this is also a business logic for many of the Chinese companies, even when you have huge variance in China.

As to structured uncertainty, as an innovation scholar, I can tell you that we have those kinds of four principles of what you need to have in order to innovate, basically, all of them about reducing uncertainty and risk because R&D is very risky and very uncertain. And, therefore, we assume that when you don't have those, like IPR, good finance, rule of law, you will not innovate. We also assume with institutions, that you have institutions that allow you to know what is the legal or at least advisable or normative action in a given point of time.

What you have in China is constantly shuffling over laws. You never really know who is answering to whom. And yet, you have constant innovation. Therefore, if you want to understand what kind of innovation happens in China, you have to understand what we call the system of structured uncertainty, how it works, why it works, and what kind of incentives does it give to people and organizations in China that want to make profit and be successful.

And it impacts their innovation strategies. It makes absolutely no sense for a Chinese company to think about producing a product that maybe will happen in ten years because they have no real sense of whether they will make it, whether they have the finance, and then even if they make it, whether they will be actually allowed to retain the product or, you know, it will somehow reach a state-owned enterprise.

CHAIRMAN SHEA: Thank you.

HEARING CO-CHAIR GOODWIN: I suppose I should admit in response to Dr. Breznitz description of the grading difficulties in science and engineering, that's one of the reasons why I was a philosophy major.

Commissioner Cleveland.

COMMISSIONER CLEVELAND: Speaking as a university member, and my research interest is persistence in college, and I think the problem of switching out is not unique to STEM students. It's across the board. We're seeing STEM may switch to the social sciences, but the social science students are also switching out of university all together, so I think there's a broader issue.

Dr. Breznitz, I'm again reading, it's a review of your forthcoming book in the Economist, and the review points out two things we haven't talked about so far, which is what they describe as the possible snags to China's success, the first being China's obsession with independent innovation, which is leading it to pour resources into dubious innovation champions, while at the same time impeding private sector companies.

And then the second issue is that middlemen bear huge risks. If high-end innovators stumble, then China is likely to be left with a lot of factories with nothing to ship.

Could you elaborate? Is that an accurate reflection of your book, and could you elaborate on those two points?

Thank you.

DR. BREZNITZ: Sure. So in the book, I actually said that the major danger to China is China itself, and specifically the central government, and specifically the push for indigenous innovation, not because indigenous innovation or innovation is bad, but when you have a system that worked very well in the Run of a Red Queen model, and that includes finance, including everything else, and you basically force it, because you, the government, think that this is what needs to happen, to do things it's not good at with a regulatory system which is against it, (a) you might risk that your own companies will just be less efficient, or even not efficient at all, and that they won't do your indigenous innovation because they don't do indigenous innovation.

The second thing that you do, and China has been really successful in that, and that's really bad for China, is you alienate and make yourself untrustworthy by your own trading partners and the multinationals that move all your jobs to it.

And you could see that in the standards policy, which has not been a great success in terms of innovation. It has been a great success in other areas, but really

not a great success in terms of innovation, and yet it made also every American and European company, at least once, very angry at China.

You could also see it in the rare earths. If I was any company that wanted to do anything with rare earths now, I would immediately start to think about something which is not China.

The second thing is the risk for the middleman, yes, there is risk for the middleman, but there is also greater risk for the innovator. So with those two risks, the risk for the middleman is probably lower because if there be a major global crisis, we'll all be bankrupt, not just China.

COMMISSIONER CLEVELAND: Mr. Atkinson, do you have any comments on bad policies that may undo the potential that China has?

DR. ATKINSON: I think there are two kinds of bad policies the Chinese have. One is simply just waste, so they throw a lot of resources at things. They have science parks that are half empty or more. But, you know, they have a lot of money to throw, and they can. In our world, you know, allocation efficiency is important because we're more private sector driven. So if we have waste, it means our private sector companies have less capital, and they can't do all these things.

In that system, it's the state, and the state has a lot of money to waste, and so I don't think, I think one of the criticisms we hear of China is, well, a lot of these projects are, if you were in a market-based economy where you're looking at rate of return or a cost-benefit analysis, you wouldn't be investing in those.

I think that's probably true, but I still think they're going to keep investing in them, and they have an enormous surplus that they can keep tapping into. So, in that sense, I don't think it's a harm to them. It's just a harm to their standard of living.

They have a little bit less money that they use for good things. But it's not going to harm their innovation system, and ultimately probably will help them because they have just so many. They throw money at this and that and that, and then whatever sticks to the wall works.

I think the areas where they have more problems is the areas where, for example, I think the dominance of the SOEs crowds out real ability for indigenous entrepreneurial companies to get space. There was a recent article I read about, whether it was true or not, but it was in the paper about an indigenous--I guess, Danny, you've talked to some of these companies--an indigenous Chinese-owned company who had its IP stolen by an SOE.

[Laughter.]

DR. ATKINSON: So then the company suffered because of that so if you want to grow, I mean ultimately the Chinese can't grow their economy on the backs of SOEs. They're going to have to transition into this more, you know, privately owned company system, and that, that I think is going to be a big barrier for them.

COMMISSIONER CLEVELAND: One more quick question. India? Where do you factor India into competition with China?

DR. ATKINSON: One of the biggest problems I see with what we've termed the "Beijing consensus" is that other countries now appear to be adopting it. Brazil, most recently, but now India. India essentially has manufacturing envy, and they're saying we want to be like these Chinese. How do we do that? So the Indians now, I think maybe in ten years, we'll have an Indian Security Economic Review Commission.

[Laughter.]

DR. ATKINSON: Or you can expand your charter maybe because the Indians are doing some things. They are things that are on the--they're considering. They haven't put them, again, in place, but things like having domestic content rules for IT, up to 70 percent over the next "x" years. I can't remember. So they're saying, you know, we want to be China. We want to produce all our IT.

Now, to me, it's an amazing thing India would even consider this because the Indian strength is in the use of IT. It's in the software and services side of the--that's where they've developed global, real global competitive advantage. And if they want to then get worse IT and more expensive IT through mercantilist policies, which is what the result will be, then it means the Tatas of the world and the Wipros of the world are just going to have to pay higher prices and be less competitive.

The Indians don't seem to quite understand that tradeoff. They're just, as I said, they really have manufacturing envy, and they're going to copy. So I think India, I'm less worried about India because I think fundamentally India will move in the right direction. India is much more, to me, like America. They have more Americanized values, I think. They're a democracy. They do have a much, they have a very strong, even though they had some state-owned companies, they have a very private sector world with CEOs who want to do the right thing.

So I think we have to really work hard to make sure India doesn't go down the Beijing consensus path, but I think they're easier to work with.

COMMISSIONER CLEVELAND: Thank you.

HEARING CO-CHAIR GOODWIN: And we're right up against the time wise, but we have, I think, time for one more set of questions.

Commissioner Slane.

COMMISSIONER SLANE: Thank you.

Real quick, I'm very interested in the STEM education issue, and you know as I see it, there really are two problems when I talk to these students. One is they say there just aren't the jobs there, so why should I spend four years getting an engineering degree, and I can't get a job, and then the difficulty.

My question is how do we incentivize these kids to do that, and I think Georgia had some program where they were subsidizing or subsidizing universities for some of these students in terms of their tuition.

I mean should these, should the government have some kind of program where there is no tuition for the first two years or some other issue there to incentivize these kids to do this? They're all going to law school, and they should be going to engineering school.

DR. BREZNITZ: So I'll be very brief. There is a set of public universities, and which we and every state have sponsored, and part of the, at least the mission of some public universities is to supply education but also to help the state. I'm in Georgia Tech, and if you look at our mission, it's very clear.

If the state of Georgia so wishes to have more engineers in its public university system, they can easily do that by subsidizing some of the tuition because the tuition rate is decided by the state. Whether it would help, it would probably help.

It would also especially help if you make STEM education actually more interesting. I mean to be absolutely fair, the first two years of STEM education at Georgia Tech is hell. And not that interesting. I've looked at some experiments, actually at MIT, where you go back to the old style of engineering so you not have a

professor here and 400 students, but you're in a virtual lab. We have the world-leading ICT. Maybe we should use more ICT in the classroom for engineering, and you start to play; right.

What those engineers want to do is to play and tinker with things. So we should think about subsidizing, we should think about also how we change the way we educate engineers, and we should think about maybe our engineering university do have a closer relationship with industry because that will solve a problem of jobs. If you already have a strong relationship with industry, just like Germany, Denmark, Finland, all those other places, by the time you finish, if you decide not to pursue a graduate degree, you basically already have a job or at least three or four interns.

DR. ATKINSON: I would just add, in part, this is a chicken or egg problem. It's going to be hard to grow the innovation economy of the U.S., including production, unless we have the talent, and if you don't have the jobs, then the talent--so we've got to do both at once. It's not just, I was thinking we shouldn't assume that better STEM education alone is going to solve the problem. You have to have demand and supply solutions at the same time.

On that problem, though, one of the areas, not the only area, but one area that's important, is we have significantly cut back on a per GDP basis NSF graduate fellowships. In the '60s, when we had the Sputnik race, we significantly funded NSF Ph.D. fellowships. If you were in engineering, you were getting your Ph.D., a lot of people got fellowships. Today that rate is very, very low. So I think that's really important thing. We could do engineering Ph.D., science and engineering fellowships.

The second thing is a little bit what Danny said. To me, one of the most interesting universities and colleges now in the country, and this is a place called Olin College, which is a very small private school. It was set up in the early 2000s. It was set up, and it's only engineering. It's about 400 students. I think about 40 percent actually are women, young women, and it is only engineering. There's no--Danny, you might not like this--but there's no tenure and there are no departments.

And its overall goal is to integrate design, business, and engineering all together. So you walk in there in your first week, and you're tinkering, you're building real products. They're on track--in our study, they're on track to producing twice as many new business startups from their students as MIT is. Twenty percent of their students start companies. I mean it's a phenomenal model. So Olin is a very small school, but it's working with the University of Illinois and with Stanford to kind of get the Olin model more deeply integrated in our engineering schools.

And it's not the only answer, but I do think it's an important answer because one of the things the Chinese don't do and can't do for a long time, their engineers are not very creative or entrepreneurial. Our engineers can be, and unfortunately our engineering education has not done that as much as it should.

So if we can take these engineers like they're doing at Olin and have them figure out how to do design, how to do business, and really go out and be entrepreneurs either in companies or on their own, I think that would be a big step forward.

HEARING CO-CHAIR GOODWIN: Thank you, gentlemen. On behalf of the Commission and staff, I'd like to once again extend our appreciation for your time today.

We're scheduled now for a ten-minute break. Thank you.

[Whereupon, a short recess was taken.]

PANEL II: CHINA'S INNOVATION INFRASTRUCTURE

CHAIRMAN SHEA: Our second panel today addresses China's state-funded research and development programs. We're going to focus on how these programs operate and what implications they have on China's ability to innovate, including within the private sector.

Joining us today are two very seasoned and distinguished experts in the field: Dr. Richard P. Suttmeier and Dr. Denis Fred Simon.

Dr. Suttmeier is a Professor of Political Science, emeritus, at the University of Oregon. He has written widely on science and technology development in China and consulted for a report on the topic contracted by the Commission.

Dr. Simon is a Professor of International Affairs at Pennsylvania State University. Throughout a long career in academia, he has researched and published on topics relating to innovation, science and technology with a particular emphasis on China and Asia.

Gentlemen, you're both no strangers to the Commission. We are grateful for your continued support and participation. As a reminder, I'll just say that we ask that you limit your remarks to seven minutes, and you know we're not bashful about asking questions.

So, Dr. Suttmeier, please begin.

STATEMENT OF RICHARD P. SUTTMEIER
PROFESSOR OF POLITICAL SCIENCE, EMERITUS
UNIVERSITY OF OREGON

DR. SUTTMEIER: Thank you, Mr. Chairman. It's a pleasure to be with you here again. An important subject, and I appreciate the chance to comment on it.

I just have a few introductory remarks. I wanted to emphasize a few things. I think one is that, as a lot of people have said, you can make all kinds of generalizations about China, and they're true in the morning and not true in the afternoon. And so I think we have to approach this whole subject with a fair degree of humility because it's a very complicated ecosystem, I think, and it's changing very rapidly, and I think we can get into that a little bit more as we go along, and as it changes, we see evidence of Chinese learning along the way.

I wanted to just remind everybody that (a) we look at China, we can see signs of enormous achievements in a variety of areas, noted in my testimony, the written testimony, but also very significant problems, and we can get into those a little bit, I think, today.

Second, I wanted to just emphasize what I would call here the drivers of research and innovation in China. We tend to think a lot, I think, about national policy and these R&D programs that you asked about, but I think we should also recognize that there are other things at work here: an enormous consumer market that is at work.

Very importantly, at the moment, I think, is the drive, the new approach to urbanization, infrastructure development. This is a very important part, I think, of the thinking about the innovation in the 12th Five Year Plan. We have resource and environmental challenges also contributing, I think, to thinking about that as well, and then a whole reservoir of entrepreneurial energy.

If you think about it in terms of sort of traditional views of innovation, what we have here, I think, are both supply factors and demand factors. In other words, there's no--China's innovation, research and innovation environment, is not driven solely by national policies. They are helping to supply the system.

But the demand is also there, and we have to think a little bit about that, especially as we get into this question of market forces as was put in the questions.

Second, once we have a sense of the drivers, I think then it's helpful to look a little bit at the institutions which are supplying the research and innovation, and here again, it's a complicated system that we want to be sensitive to those complications.

There's first of all an academic system, characterized by the work of the universities and in particular the Chinese Academy of Sciences. There's this whole very large industrial sector that's very complicated, and I think it's kind of a mistake to focus solely on SOEs, as we heard a little bit in the first session.

I think in my written presentation, I note how these, the industrial sector is differentiated by ownership. It's differentiated by size. It's differentiated by levels of internationalization in a variety of ways. So we want to keep that in mind.

Thirdly, there's a very important defense sector. You will hear more about that this afternoon.

Fourth, there is also a government research institute sector serving such things as agriculture, such things as public health, such things as environmental

protection, as well. So that whole government research institute part of it is another part of the story.

And then, finally, you've got the multinational corporations. So when you think about this innovation system in China, it's a really complicated system, and it's big, and the interesting question is to what extent does it cohere? To what extent do you begin to have positive cooperation across it?

Recently, the Chinese have begun to talk about "xietong chuangxin," which can be translated as collaborative, or cooperative, innovation, which is a little bit different from the "zizhu chuangxin," which is the indigenous innovation. So this xietong chuangxin is pointing to new possibilities of cooperation, both I think within China, among these different sectors, and within the international environment, as well.

Add to this mix a much more robust presence and role for local governments. We heard a little bit about that from Danny Breznitz. And some very interesting new experiments going on--I think Denis will say a little bit more about this--where local governments are building platforms for industry, university, government research collaboration.

Problems. Many. I think the Chinese are very aware of these. I list a few of them in the paper. They include what I've called here the "Steve Jobs problem," which is on the occasion of Jobs' death, the Chinese were asking themselves “why don't we have our own Steve Jobs,” and this reflects, I think, some feeling of disappointment about the level of creativity and innovativeness in the system.

Incidentally, I think at least one city has initiated its own policy now and plans to produce Chinese Steve Jobs.

Second, the system is rife with corruption and misconduct, both at the level of research, but also in terms of production, product quality, and all those things that you know about.

Third, some very serious management problems or national administration problems. There is, as Rob Atkinson alluded to, there's so much money sloshing around in China right now, that it's really not being used very well, and I think the central authorities and the Ministry of Finance are beginning to ask very difficult, tough questions about that.

There are a lot of stovepiping problems that still exist. There are ongoing problems of research, relationships between research to production in spite of these new initiatives, but it's an enduring problem.

And then I think there is this, what I've called here, "what is indigenous innovation in a world of globalization problem"? And I think that there are some very significant changes beginning to happen in the way China answers that question. But it's an ongoing tension. To what extent do you focus on indigenous innovation? To what extent do you link up with the global production system of the sort that Dan Breznitz talked about?

So I don't want to take up any more time. I think there is a lot of time for questions. But I would just reiterate, again, that (a) what is true in one circumstance may not be true in another circumstance; (b) the system is changing very rapidly in a variety of ways; and (c) I think there is a lot of policy learning going on so that when the Chinese begin to confront problems, they take them seriously. They look at them. They are constrained from solving all of them by political factors, but nevertheless

they're aware of them.

Thank you.

PREPARED STATEMENT OF RICHARD P. SUTTMEIER
PROFESSOR OF POLITICAL SCIENCE, EMERITUS
UNIVERSITY OF OREGON

May 10, 2012
Richard P. Suttmeier
Professor of Political Science, Emeritus
University of Oregon
"Testimony before the US-China Economic and Security Review Commission"
Hearing on "Chinese Innovation: Implications for the United States"

Members of the Commission. Thank you for the opportunity to present some of my views on this important topic. It is a pleasure to be here with you again.

The subject of innovation in China has attracted worldwide attention in recent years, and there has been much disagreement about China's innovational capabilities and achievements. I think we are gradually coming to a better understanding of these issues as seen for instance in a series of useful reports on the subject, including the report submitted to the Commission last year by CENTRA Technology.[1] These various studies are giving us a better sense of the assets and liabilities China brings to the challenges of innovation. Let me consider some of these briefly here.

China is clearly demonstrating a capacity for significant research and engineering achievements as seen, for instance, in the growth of scientific papers published in international journal and notable engineering accomplishments in such fields as space, ocean engineering, supercomputing, materials technology, and hydraulic engineering. At the same time many Chinese associated with innovation policy, and a number of foreign observers, recognize significant problems with China's national innovation system.[2] To begin to understand these somewhat conflicting phenomena, it is helpful to look at some of the more important aspects of China's innovation ecosystem.

At the outset, we should recall that there are powerful drivers of innovation at work in China. In addition to the serious commitment to national action plans for innovation from the political elite, these would include an enormous consumer market, important trends in urbanization and infrastructure development (both engendering large-scale public investments), major resource and environmental challenges, and an enormous reservoir of bottom-up entrepreneurial energy.

Located between these drivers and the successful and not so successful outcomes of research and innovation activities is a set of institutions of considerable diversity. These include, first, a sector of academic research led by the Chinese Academy of Sciences (CAS) and China's leading universities. A second sector of industrial research and innovation involving Chinese companies is characterized not only by differences among various type of industry, but also by notable regional, ownership, and size

[1] *China's Program for Science and Technology Modernization: Implications for American Competitiveness.* See also, The World Bank. *China 2030: Building a Modern, Harmonious, and Creative High-Income Society* ("Supporting Report 2") (2012); The Center for American Progress. *Rising to the Challenge* (2011); and the recent brief report produced by McKinsey's Shanghai office, "How China Is Innovating." (2012)
[2] Cf., OECD. *OECD Reviews of Innovation Policy: China*. 2008.

differences. Thus, it is difficult to generalize about the nature of innovation in a sector that includes large state-owned enterprises and private firms, which displays both the effects of powerful central planning and the play of entrepreneurial energy, which includes firms that are deeply involved with global production networks, and those that are more purely domestic in orientation, and firms with highly cosmopolitan professional staffs, and those whose experiences are largely limited to economic activities in China. The institutional mix is further complicated by the existence of a large defense sector which is increasingly committed to the development of dual use technologies and civil-military integration, by other government research institutes supporting the supply of public goods (agriculture, health, environment, etc.), and finally by the presence of multinational corporations, some 1300 of whom now have R&D centers in China of one sort or another.

In short, it is difficult to talk about a simple undifferentiated national innovation system in the face of such diversity, especially when we consider the growing role of local governments in supporting research and innovation. In addition, at both national and local levels, we see interesting initiatives at institutional innovation in support of new public-private partnerships and new innovation "platforms" to facilitate the development of networks of cooperation among industry, universities, and government research institutes in support of the policy objective of *xietong chuangxin* ("cooperative," or "collaborative," innovation).

As you know, China is providing resources for this system of institutions with increasingly generous funding, attention to the cultivation and recruitment of technical talent, and the provision of a variety of technical support services, including those focused on the creation and management of intellectual property. China has also been creative, and largely successful, in exploiting globalization to promote its science and technology. It has tapped into the diaspora of Chinese scientists and engineers in profitable ways, it has exploited opportunities for advanced overseas training, and it has developed a robust approach to international scientific cooperation. With its mix of domestic support policies and international outreach, it is becoming a magnet for MNC R&D investments, for foreign professionals seeking research opportunities in China, for Chinese scientists and engineers who once were lost in the brain drain, and for foreign governments seeking to build scientific and technological cooperation with China.

In spite of these many positive developments, China's innovation system also faces a number of problems. These include, first, widely expressed concerns that Chinese research and innovation are characterized by a serious lack of originality and creativity - what might be called the "Steve Jobs problem."[3] In addition to the creativity issue, and probably related to it, are the issues of serious scientific misconduct and widespread problems of commercial integrity. To these could be added problems with existing institutional arrangements - R&D spending outpacing good management, problems of stove piping and national coordination, long-standing problems of research and innovation in industrial enterprises (weak in-house R&D, weak linkages between research and economy) which have stubbornly defied easy solution, and finally, an unresolved tension between techno-nationalist and techno-globalist impulses (or, the "what does 'indigenous innovation' mean in an age of globalization?" question).

Explanations for these problems, and why China's aspirations for innovation are sometimes frustrated,

[3] On the occasion of Jobs' death, many Chinese were asking why China has not and, perhaps, could not produce a Steve Jobs. In response, the city of Ningbo, reportedly, initiated a new plan to produce Steve Jobs!

involve economic, cultural institutional, and political factors. In economic terms, we can point to some serious disincentives (abundant labor, narrow profit margins, availability for foreign technology, etc.) which discourage innovation. Culturally, the education system is weak on encouraging "outside the box" thinking, and continues to promote excessive respect for hierachical authority. Institutionally, the weak rule of law generally, and weak intellectual property rights protection more specifically, combined with inappropriate venture financing, frustrates innovative activities. Finally, in political terms, the strong belief in state directed, top-down innovation biases the innovation system away from what could be more productive bottom-up approaches, and an information culture which privileges political control of information as a default assumption, also imposes constraints on the innovation system. Certainly, by Western assumptions about innovation, China seems to be trying to "square the circle" by simultaneously calling for the creation of an "innovative society" while also seeking to enforce the tenets of a "harmonious society" by authoritarian means.

In the remainder of the submission, let me try to address some of the more specific questions you have raised.

1. How do such national programs as the 863 and 973, the key laboratory program, and the Medium and Long Term Development Plan (MLP) affect innovation in China?
First, it is important to note that these numbered programs (863, 973) of the Ministry of Science and Technology (MOST), while important, represent a relatively limited percentage of national expenditures on R&D. The share of the R&D budget directly controlled by MOST is estimated to be less than 20%, and this includes more than the numbered programs. That said, these programs have undoubtedly helped Chinese scientific and technological development. The question, though, has been whether they have been cost-effective. 863, for instance, was originally conceived as a program for catching up with the international frontier in high-technology. While it certainly has contributed to high-tech development in a variety of fields, the international frontier itself has not remained stationary. It is not clear whether 863 has led to a reduction in the gap between the two, or a widening.

Another critical question about these programs has been, and continues to be, whether they are administered properly. Questions have been raised about the quality and suitability of peer review in decision-making about program priorities and project funding, and about the susceptibility of the programs to corruption. In the views of at least some scientists, the programs have not really fostered original research and innovation, and the reason lies with the administrative arrangements and institutional design.

With the initiation of the MLP, China launched a multifaceted strategy of national mobilization in support of science and innovation involving major research initiatives and a number of supporting measures intended to more fully integrate national R&D projects and industrial policies. Again, there is little doubt that the set of policies making up the MLP are advancing Chinese capabilities in research and innovation, but the question of cost effectiveness is again prominent. A great deal of money for research and innovation is now "sloshing" around China, but there seems to be a growing concern that funding increases have outpaced sound administration.

It is fair to say, I believe, that the history of China over the past three decades indicates that Chinese leaders take the country's problems seriously, learn from mistakes, and in an iterative fashion, attempt to correct institutional failures. There is again, today, active discussions about future reform of the S&T

system which recognize that the next steps in reform will not be easy. But, there is also a recognition that the future performance of the innovation system is contingent on them.

Finally, it is important to recognize that one of the more important aspects of the MLP is its emphasis on research and innovation in industrial enterprises in order to make the enterprise sector the core of the innovation system. This has led to a redirection of policies in favor of enterprises as seen, for instance, in a greater share of 863 money going to industry and the establishment of new national laboratories in companies.

2. Is China's model of highly centralized R&D planning effective? Does China's leadership appear to be adhering to this model or moving away from it?

The effectiveness of centralized R&D planning is, to some extent, a function of the nature of the work at hand. China's success in major engineering projects, such as those noted above, is due in part to a centralized scheme to mobilize resources to attack high priority technological missions.[4] In this sense, China is not unique; such an approach is found in many other countries, including the United States. However, the appeal of this centralized planning model is more deeply ingrained in Chinese decision-makers than is the case in other countries in part because of the success of the strategic weapons programs of the past, and the belief that former major planning efforts have effectively advanced Chinese scientific and technological capabilities. In addition, this approach is seen as suitable for a developing country as it seeks to "catch-up" to international frontiers, and, again, one can find evidence of its effectiveness in other countries.

This model is less appropriate for other projects, though, and for moving beyond "catch up." The emphasis upon centrally directed programs can work against curiosity driven research and bottom-up entrepreneurial innovation. For instance, there have been a number of allegations that Chinese entrepreneurial startups have been disadvantaged by China's policy profile which, until recently, tended to be insensitive to innovation initiatives that were not part of the plan and the policy benefits therein.

We should recognize, though, that the Chinese innovation system should not be characterized, solely, as being driven by central research and industrial planning. As noted in the discussion of institutional variety, above, the innovation system is too complex and variegated to be described in simple terms. In addition, in terms of research programs, curiosity and investigator driven projects are eligible, although

[4] It is notable, in this context, that in a recent ranking of the top 10 S&T news stories for 2011, chosen by academicians of the Chinese Academies of Science and Engineering for the *Science and Technology Daily*, the majority involved projects that would likely benefit from centralized planning and direction. The top 10 included:

1) The successful test flight of the J-20stealth fighter;
2) The first time a national science and technology award was revoked because of fraud;
3) The launch of three more navigation satellites to support the Compass navigation system;
4) The discovery that body cells can be directly induced to become liver cells;
5) China's first fast neutron reactor becoming part of the power grid;
6) A Chinese made manned submersible reaching a record depth of 5000 m;
7) The "Chang-e II" moon probe satellite reaching the L2 Lagrange point, allowing Chinese scientists to probe targets in deeper space;
8) Tu Youyou winning the Lasker Award for work on artemisinin;
9) The Shenzhou-8 capsule docking successfully with Tiangong-I; and
10) The success of the University of Science and Technology of China in working out an eight-photon entangled state.

these usually have to fit into some sort of predetermined program definition. Those program definitions are more demanding at the Ministry of Science and Technology (MOST) than they would be at the Chinese National Science Foundation (NSFC), although even at the latter, the programs for larger grants specify program objectives into which projects must be fitted.

It is unlikely that the deep-seated preferences for a centrally planned system will be abandoned any time soon in large part because, in some circumstances, they have worked well. However as China attempts to move beyond catch-up, as it seeks to better utilize the pools of technical entrepreneurial talent that exist, and as it interacts more fully with the global innovation system, the use of the centralized R&D planning model is likely to be more circumscribed.

It is useful, in this context, to recall that the distribution of activities in China's national R&D profile reflects the overwhelming preference for technological development (over 80% of national R&D expenditures), as opposed to basic and applied research. The administrative arrangements for development work will differ markedly from the exploratory activities of basic and some applied research. As China seeks to "leapfrog" into leading positions in new science-based industry, it will have to give greater attention to exploratory research and to new approaches to R&D management and administration.

3. What are the prospects for more market-driven innovation? Is there any real innovation going on in China's private sector?

As the discussion above suggests, we can expect market-driven innovation to become much more important in the coming years. But we should also recognize that market-driven innovation is already well-established and widespread. As Kevin Wale, president of GM China, noted recently, "What China does better than any place else in the world is to innovate by commercialization, as opposed to constant research and perfecting the theory, like the West. When the Chinese get an idea, they test it in the marketplace. They're happy to do three or four rounds of commercialization to get an idea right, whereas in the West, companies spend the same amount of time on research, testing, and validation before trying to take products to the market."[5] Wale goes on to note, "in our business in China, if we don't innovate through commercialization, we're going to lag behind our competitors." Market forces drive the "shanzhai"[6] culture characteristic of South China, and lie behind diverse innovations in consumer products more generally, as well as in business model innovation and innovations in supply chain management, areas where China is also often seen as a trend setter.

The play of market forces also helps explain why there is considerable innovative activity in the private sector, in spite of policy preferences being biased against private companies. There is a growing recognition that the policy preferences enjoyed by state owned enterprises protect them from market forces and actually work against the cultivation of cultures of innovation in those enterprises.

Various indicators support the view that the private sector has become active in innovation. For instance, according to 2005 figures, of the103 companies which were designated by MOST as "experimental

[5] Kevin Wale. "Automotive Innovation in China: The View from General Motors." In, McKinsey report. "How China Is Innovating."

[6] "Shanzhai" has come to describe the practice of copying or imitating foreign technology (often without regard to IPR), and then adding distinctive functionality to a device, at lower cost, that responds to Chinese market preferences.

innovative enterprises" that year, 77 were private. Of the 10 most successful Chinese companies in securing invention patents in 2009, eight were private. Other research shows that private companies take their R&D missions more seriously than SOEs in terms of the intensity of expenditures and the recruitment of qualified technical personnel. In order to capture more of the entrepreneurial energy found in the private sector, it appears as if the national government and local governments are doing more to support the expansion of private sector innovation oriented firms.

CHAIRMAN SHEA: Thank you, Doctor.
Dr. Simon.

STATEMENT OF DR. DENIS FRED SIMON
VICE PROVOST OF INTERNATIONAL STRATEGIC INITIATIVES
ARIZONA STATE UNIVERSITY

DR. D. SIMON: Thank you.

I too want to thank the members for the opportunity to address them about this issue of innovation in China.

As Rob Atkinson mentioned, I too just returned from the U.S.-China Innovation Dialogue in Beijing, and I think we actually learned a lot of interesting things about some of the dilemmas and some of the challenges that China faces as it seeks to improve its innovation performance.

I thought as a way to complement what Pete did, what I would do is talk about two things. First, the differences in the policies that are being articulated in this new 12th Five Year Plan for Science and Technology; how it contrasts with the 11th Five Year Plan we just finished. And second, to look at some of the ongoing discussions that have been occurring in China, particularly over the last 12 months, about how the system must reform itself in order to improve innovative performance.

I think both of those things indicate in some ways the direction that China is moving, and what it hopes to accomplish if, in fact, it succeeds in reforming the system in these new directions.

I think it's important to understand, however, that despite the fact that a lot of people saw China come out of the 2008 Olympics with a great deal of self-confidence, with a great renewed sense of vibrancy in terms of its national purpose, I would argue that in the realm of science and technology affairs, the leadership really has been beset by a growing sense of apprehension and even anxiety about the failure of its science and technology system to deliver the type of performance expected, given some of the significant increases in resources and attention that's being thrown at the innovation problem.

So while we may see a lot of growth in terms of some traditional metrics like patents, increases in the number of cited papers, et cetera, I would suggest the reality is that something, in fact, is seriously missing in terms of the anticipated commercial impact associated with these growing numbers.

In the aftermath of the global financial crisis, Chinese officials believe that the world has embarked on two new technological revolutions: one in the life sciences and biotechnology and the other in clean energy technologies. Today's leaders have committed themselves to China playing a very prominent role in these industries, and they want to be, in fact, among the leaders in driving the advanced frontiers in biotech and clean energy.

At stake for Chinese leaders, I would argue, is more than just competitive advantage in economic terms, though that's very important. The paramount drivers, I would argue, are political.

Failure to make significant progress along the innovation curve would leave China not only unable to facilitate its own critically needed economic transition, but it also would leave China with a sense of political exposure that simply is unacceptable to

Beijing.

In contrast to a lot of people who see China as having already become an unstoppable juggernaut that increasingly is dominating or seeks to dominate the global economy, I take a rather different tack. If we look at the 12th Five Year Plan, we see a change in the flavor of how China is thinking about its innovation dilemmas. Compared with the 11th Five Year Plan, for example, the Chinese use the term "gongjian," which means conquer, as in a battle or a conflict.

This is very different than the image portrayed in the 11th Five Year Plan, where China basically saw the transition to a knowledge economy as simply a change in the foundation of its economic base.

The promotion of indigenous innovation, which in the United States has become almost an anathema to the entire U.S. government and the American business community, I think is stressed even more strongly in the 12th Five Year Plan.

The 11th Five Year Plan identified many problems in the S&T system in terms of weaker original innovation capability, a shortage of high-level personnel, poor efficiency, and allocation of resources. In the 12th Five Year Plan, they talk about these same kind of problems but also add an additional problem, quote-unquote, "disorder in the prevailing institutional mechanisms" for supporting S&T advancement.

The very real dissatisfaction with progress along the path of greater indigenous innovation in China is manifested in the large number of national and regional media reports in China observing the local visits of senior officials such as Li Changchun, Wu Bangguo, as well as Hu Jintao and Wen Jiabao, all of whom have been traveling around the country admonishing provincial and municipal officials to make greater efforts to promote indigenous innovation.

One particularly interesting change in the 12th Five Year Plan is the removal of one of the key indicators of technology development highlighted in the 11th Five Year Plan, namely, the metric for calculating dependence on foreign technology. The so-called "40 percent" metric or hurdle appears to have been taken out of the newest Five Year Plan, perhaps because Chinese leaders recognize that much of the technological advance in China today necessarily will be a product of the blending of both foreign and domestically derived technology.

Two other elements were added in the 12th Five Year Plan. One is this new emphasis on the building and strengthening of innovation bases and collaborative platforms, and the other involves the explicit emphasis on the further growth of high-level talent.

In spite of the huge quantitative jump in the number of scientists and engineers, the reality is that China still faces a serious talent shortage in terms of the supply of qualified individuals with either advanced technical or managerial skills.

The official launch of the 12th Five Year Plan was augmented by the publication of an important article written by Premier Wen Jiabao in July 2011 in the magazine "Qiushi," which is a Party journal. In a remarkably frank statement, Premier Wen notes that, quote-unquote, "Chinese capacity for indigenous innovation is weak, that Chinese industrial technology is at a low level, and that both Chinese basic and cutting edge research are relatively unimpressive."

He states rather explicitly that "the Chinese science and technology system is incompatible with the needs of economic and technology development."

Even further on in the document, he goes on to say, "China lacks original

innovation capability; rarely does it propose new issues, new theories or new directions in science; and core technology is still controlled by others, and many important industrial technological needs rely on foreign countries."

I would argue that this article in Qiushi plus the changes in the 12th Five Year Plan have engendered a rather new approach or a new set of thinking in China about what direction to take.

First, I think the idea that the system is not really working well has induced the notion that perhaps maybe even some radical changes are needed in the system. I don't think the fact that the Chinese leaders have an ambitious agenda will change. But the fact is that China is simply not going to be satisfied by accepting a more limited role as a process-oriented incremental innovator in the global innovation system.

Second, the increasingly imperative nature of achieving greater innovative performance seems to be driving China further in the direction of spurring innovation using the market and using enterprise.

It's also driving a greater degree of urgency for greater IPR protection, again, as noted before because even Chinese enterprises today are feeling the crunch.

And finally, and most importantly, it has awakened a new sensitivity to the dynamic role to be played by small- and medium-sized firms in the innovation system. I think this portends a big shift away from the current focus, which has been on SOEs. Add to this mix the growing role of foreign R&D centers, the increasing numbers of returnees, and it can be said that the innovation landscape in China may be poised for a dramatic change in terms of its center of gravity.

Will it lead to a substantially more innovative China -- only time will tell. But one thing is clear, namely, that the necessity of enhancing the innovative performance combined with a renewed inclination to clean up some of the bureaucratic problems that presently confound the system seems to have unleashed a new willingness to experiment and break down existing sacred cows alongside the entire science and technology machinery in China.

Thank you very much.

PREPARED STATEMENT OF DR. DENIS FRED SIMON
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China's New S&T Reforms and their Implications for Innovative Performance

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Arizona State University

Testimony before the US-China Economic and Security Review Commission
May 10, 2012

I would like to thank the Committee for providing me an opportunity to address the members regarding the issue of innovation in China. Having just returned from China this past weekend, where I participated in the US-China Innovation Dialogue as a member of the American experts group, I had a chance to gain a firsthand view of the latest Chinese thinking about the opportunities and challenges they face in fostering fundamental improvements in their innovation capabilities and performance. I also had a wonderful opportunity not only to exchange ideas with long-term friends and associates within China's Ministry of Science and Technology (MoST) and the Chinese Academy of Sciences (CAS), but I also had the benefit of several productive meetings with the local S&T bureau in both Wuhan (in Hubei province) and Chengdu (in Sichuan province), respectively. These meetings afforded me an opportunity to deepen and broaden my understanding of where Chinese officials think they stand today in terms of their innovation trajectory and what hurdles they must overcome if their country is to move in the direction of shifting from a manufacturing oriented to a knowledge-driven economy.

The committee has asked me to present some of my views on where China stands in building an infrastructure to support its innovation drive. Perhaps the best way to consider this issue is to examine two items. First, I believe it is important for us to analyze the differences between the policies and initiatives contained in the recently concluded 11th Five Year S&T Plan (2006-2010) and the current 12th Five Year Plan for S&T (2011-2015). And second, I think it is important for us to consider and review the very important on-going discussions that have been occurring in China over the last 12-18 months regarding the next stage of S&T reform in China. By providing some insights into both of these matters, I believe we can secure a better grasp of China's current concerns and apprehensions regarding its own innovation capabilities.

From my perspective, the issue of China's efforts to create a more innovation oriented economy has been embedded in a great deal of hyperbole, exaggeration, and embellishment. The media, combined with an increasingly larger and larger segment of the policy community, seem to be caught up in conjuring up the image of China as a steadily emerging, albeit significant, technology threat to the United States. Very little in-depth serious research has been conducted on Chinese innovative performance across the broad range of key sectors that are the focus of China's national and local policymakers. While there is little doubt that Chinese leaders have articulated ambitious goals and intentions for catching up and even leap-frogging Western countries in some key technological fields,

the reality is that China has a long way to go before it presents a serious overall threat to US competitiveness and scientific leadership.

In the 1980s, when China S&T specialists were asked why China lags significantly behind the West and Japan in science and technology, most responses focused on three critical deficits: 1) not enough money to support meaningful R&D at all levels; 2) not enough talent in terms of qualified scientists and engineers; and 3) a backward infrastructure that had little modern equipment and advanced computing capability. Ironically, when somewhat that same type of question is posed today, the first response among most serious experts would be: 1) there is more than enough money, with R&D/GDP spending growing some twenty-plus percent over the last half dozen years; 2) there seemingly is more than enough talent with undergraduate and graduate enrollments in science and engineering continuing to grow since 1999 by leaps and bounds; and 3) there is more than enough equipment considering the fact that today China has some of the most modern laboratories in the world with some of the most advanced equipment in place. So, one might then ask, so what is wrong? What's not working? What is the problem?

Unlike many who believe that post Olympics 2008, Chinese leaders have exhibited more self-confidence and perhaps an ample dose of arrogance in the midst of a pronounced surge in nationalism, I would like to suggest that in the realm of science and technology affairs, China's leadership has been beset by a growing apprehension about the failure of their S&T system to deliver the type of performance expected given the significant increases in resources and attention being thrown at the innovation system at all levels. While traditional metrics such as growth in numbers of patents and increases in the number of SCI citations all seem to suggest China is on the road to becoming a more significant player in the global innovation system, the fact is that there is something missing in terms of the anticipated commercial impact associated with these growing numbers.

In the aftermath of the global financial crisis, Chinese leaders have focused much of their attention on what they believe will be a new era of profound change in the realm of science and technology. More specifically, along with the continued importance of information technology and new materials, PRC officials believe that the 21st century will be dominated by two new technological revolutions, one in life science and biotechnology and one in cleaner alternative energy and associated technologies. Whereas China largely missed out on both the microelectronics and computer revolutions because of the debilitating effects of the Cultural Revolution (1966-76), today's leaders have committed themselves and the Chinese S&T community to ensure that China plays a prominent, if not leadership role, in developing and driving the advanced frontiers in biotechnology and clean energy. At stake for Chinese leaders is more than just competitive advantage in economic terms, though this clearly is important, especially as one tries to understand the specific drivers underlying the massive push for indigenous innovation. The paramount drivers are political and have been political since 1978 when the PRC launched its so-called "four modernizations program." Having had to deal with the technological problems brought on by the Sino-Soviet rupture in the late 1950s as well as confront the restrictions on technology transfer imposed by the former COCOM and the continued efficacy of US export controls, Chinese leaders view greater technological autonomy as the primary way to diminish, if not eradicate, the ability of the US or any other nation to use denial of access to technology as a form of leverage designed to influence Chinese behavior, internal and external. Thus, failure to make significant progress along the innovation curve leaves China not merely unable to facilitate its own critically needed economic transition, but it also leaves China with a sense of political exposure that simply is unacceptable to Beijing.

Unfortunately, for PRC officials, as suggested earlier, the Chinese innovation machine has not proven to be the unstoppable juggernaut that increasingly seems to be the picture painted by many Western observers. In the new 12th Five Year Plan for S&T, there is a striking change of tone in the language deployed when compared with the 11th S&T FYP. For example, the term "gongjian" (conquer as in a battle or conflict) is used in the 12th S&T FYP when discussing the promotion of indigenous innovation; instead of portraying the move towards an innovation-driven nation as largely a change in the foundation of the Chinese economy, it is now put forth in terms of a being "crucial stage" in the overall development of the country. The promotion of indigenous innovation—which seemingly has become an anathema to the entire US government and American business community is stressed even more strongly in the 12th S&T FYP. The 11th S&T FYP identified many existing problems in the S&T system, including a) weak original innovation capability; b) loose linkages between industry and research; c) a shortage of high level innovative S&T personnel; d) poor efficiency in the allocation of resources; and e) need to further deepen the implementation of indigenous innovation policy. In the 12th FYP, these same problems also are highlighted, but added to the list is a new problem dealing with "disorder in the prevailing institutional mechanisms" (jizhixing zhangai) for supporting S&T advancement. Moreover, it also is noted that because of the still underdeveloped nature of Chinese indigenous innovation capability, the country has not been able to make sufficient progress the domain of economic and social sustainability.

The very real dissatisfaction with progress along the path of greater indigenous innovation capability is noticeably manifested in the large number of national and regional media reports in China observing the local visits of senior leaders such as Li Changchun and Wu Bangguo as well as Hu Jintao and Wen Jiabao—all of whom have been traveling around the country admonishing provincial and municipal officials to make greater efforts to promote indigenous innovation. The repeated messages about the promotion of indigenous innovation appear to highlight a distressing gap between the S&T aspirations of the central government in this area and the reality on the ground in terms of both enterprise behavior and the lack of tangible success at the local government level in helping to realize Beijing's explicitly stated goals.

One particularly interesting change in the 12th S&T FYP is the removal of one of the key indicators of "technology development" highlighted in the 11th S&T FYP, namely, the metric for calculating "dependence on foreign technology." The so-called "40%" metric appears to have been taken out of the newest FYP document, perhaps because Chinese leaders recognize that much of the technological advance in China necessarily will be a product of the blending of both foreign and domestically derived technologies and that the effort artificially to lessen the utilization of imported technology and know-how might actually stifle some forms of domestic innovative activity.

Two other elements also were added to the 12th S&T FYP. One is the new emphasis on building and strengthening innovation bases and platforms. The focus here appears to be on more effectively leveraging and sharing key technological resources and equipment to support innovation efforts. This also may mean greater emphasis on harnessing technology clusters to harvest innovation. The other element involves a more explicit emphasis on the further growth of China's high-level talent pool and the creation of a number of "innovation teams" to bring together innovative people. In spite of the quantitative jump in the numbers of scientists and engineers in China, the reality is that the PRC still faces a serious talent shortage in terms of the supply of qualified individuals with either advanced technical or managerial skills. Taken together with the other changes noted above, the 12th S&T FYP projects a more imperative tone and greater sense of urgency in advancing the country's capabilities for

achieving indigenous innovation.

The official launch of the 12th FYP for S&T was augmented by publication of an important article written by Premier Wen Jiabao that appeared in the CCP journal titled "Qiushi" (Truth) in July 2011. Premier Wen's article seems to have provided the impetus for a very wide ranging debate and discussion about new directions for S&T reform in China. In a remarkably frank statement, Premier Wen notes that "Chinese capacity for indigenous innovation is weak, that Chinese industrial technology is at a low level, and that both Chinese basic and cutting edge research are relatively unimpressive." He also states in rather explicit terms that "the Chinese science and technology system is incompatible with the needs of economic and technology development." Clearly, Premier Wen takes care to note the major progress China has made in terms of manned spaceflight, high speed rail, experimental fast reactor, superconductivity, hybrid rice, gene sequencing, and supercomputing (the Tianhe-1) and the development of a high performance processor (Loongson). Nonetheless, Premier Wen is quite strident in his comments about where China stands: "China lacks original innovation capability; rarely proposes new issues, new theories or new directions in science; and core technology still is controlled by others and many important industrial technological needs rely on foreign countries."

Finally, but perhaps most critical, Premier Wen discusses the inherent flaws in the existing science and technology management system, citing three critical deficiencies: a) the existence of structural and institutional obstacles for achieving a market oriented technological innovation system with enterprises as the mainstay; b) the macro S&T decision making mechanisms and organizational structure is irrational—caused by institutional fragmentation; and c) the enthusiasm and creativity of the majority of scientists are not fully mobilized. To remedy these defects, he presents three measures: 1) accelerate the onset of the enterprise-led technology and R&D innovation system; 2) clarify the role and functions of the market, government and enterprises, and especially accelerate the transformation in the role of the government, including establishment of separate operating mechanisms for S&T decision-making, policy implementation, and evaluation ; and 3) continue to push forward with reform of scientific research institutes.

As suggested, the Qiushi article seems to have sparked the beginning of a major series of policy discussions about the directions for S&T reform, with some sources even suggesting that the Ministry of Science and Technology be abolished and its operating functions be transferred to the Ministry of Education, the Ministry of Industry and Information Technology, etc. MoST has been the object of frequent criticism, particularly concerning the inefficiencies associated with the way it allocates research project monies. In this regard, there also have been suggestions that China perhaps needs an overarching organization similar to OSTP in the US. From the Chinese perspective, such an organization would have the clout and capacity to serve as a paramount coordinating mechanism for helping to drive macro-level policy while leaving the day-to-day functions of providing research grants and allocation R&D funds to other ministries and related organizations. While it seems unlikely that MoST will be abolished or even that such a decision would be the right option to pursue, the fact that such a radical possibility has even surfaced further suggests the leadership continues to search for an adequate solution to the continued poor performance of the innovation system.

The imperative nature of the issue also can be seen in just how rapidly the Chinese S&T system has responded at lower levels to a call for enhancing innovative performance and fixing the problems that surround the operation of the innovation system. In February 2012, the media reported that Nanjing had been selected as a pilot city for national S&T reform. Nine new policies were identified focusing on

the management of scientific and engineering talent, greater technology protection, and the encouragement of technology startups. In that same month, Shandong province announced that it was launching an effort to establish a new management system to strengthen supervision and management of S&T activities, establish the dominant position of enterprises, promote deeper cooperation with the Chinese Academy of Sciences, Chinese Academy of Engineering and the China National Natural Science Foundation, and build a more flexible talent pool to enhance S&T innovation efforts. In March 2012, Guangdong province issued a similar series of pronouncements, with Li Xinghua, the Director General of the S&T Department of Guangdong province, stating that a series of newly created research institutions would become the focal point for helping to deepen S&T reform and improving regional innovation. In addition, Guangdong province is the first province in China to launch formal legislation concerning indigenous innovation and its application—a reflection of that province's intention to move quickly and expeditiously away from its current economic orientation. Both Hubei province and Xinjiang also initiated efforts in the same month to embark on a new phase of S&T reform, suggesting that the entire S&T system has been engaged in the process of deliberating how to introduce and implement major changes into their local S&T structure. With the growing role of the localities in providing financial support for innovation efforts and the clear steps being taken to bring innovation-related decision-making closer to the point of actual R&D and related activities, the actions at the local level reflect the seriousness with which the central government's directives are being received and acted upon.

All of the actions described reflect three important trends that have implications for how we view the thrust and direction of China's innovation efforts. First, the current system clearly is not working well and several radical changes seem to be in the making. Just how far the leadership is willing to go to unleash China's full innovative potential remains to be seen. A general tone of dissatisfaction continues to pervade the highest echelons of power in Beijing in terms of the real imbalance between the growth in S&T inputs and resources and the limited achievements on the output side in terms of real innovative breakthroughs. While some observers of China's innovation system have argued quite persuasively that the PRC's strong emphasis on indigenous innovation and push for radical versus incremental innovation represents a costly mistake and misallocation of resources, the fact remains, however, that Chinese leaders have an ambitious agenda for science and technology advance that simply will not be satisfied by accepting a more limited role as a process oriented, incremental innovator in the global innovation system. The political will and desire in China to be among the global technological leaders simply will continue to trump the apparent economic logic of such a more limited role.

Second, the increasingly imperative nature of achieving greater innovation performance seems to be driving China in the direction of greater reliance on the market for spurring innovation, especially as more and more initiative and investment is being expected from the enterprise. In addition, it also is driving a new sense of urgency for enhanced IPR protection, especially from inside of China from among Chinese enterprises, many of whom appear just as worried as their foreign counterparts about IPR theft, copying, pirating, etc. This is not surprising since this is very similar to the path taken by Japan, South Korea, Taiwan, and Singapore as they moved from their prior emphasis on low cost manufacturing to more R&D and design oriented emphases in their economies. This could bode well for Western, Japanese and Korean firms, among others, who have lobbied strongly and steadfastly for stronger IPR legislation and enforcement in China over the last decade or longer.

Finally, the growing focus on the enterprise in terms of innovative initiative, which initially had been adopted as a major policy thrust in the "15 Year Medium-to-Long Term Plan for Science and

Technology (2006-2020)" launched in early 2006, seems to have awakened a new sensitivity to the dynamic role to be played by small and medium firms in the innovation system. It is clear that heretofore large, state owned enterprises have been the major beneficiary of the central government's strong emphasis on innovation and technological advance. Many of the firms on the list of China's so-called "most innovative enterprises" issued by MoST are indeed SOEs. Frequently, they have been given significant access to capital and related resources that simply have not been available to smaller firms. As of the result of the new S&T reforms and the questions raised by both domestic and foreign experts, e.g. World Bank 2030 report, however, there is a renewed emphasis on the catalytic role that SMEs could play as engines for bringing new ideas to market in ways that larger firms simply are unwilling or will-equipped to do. In some ways, therefore, we may be witnessing the emergence of a new architecture of innovation in China, one with more impetus coming from the local versus central level as well as one where smaller firms can receive the necessary support and guidance to allow them to become successful component of the Chinese innovation system. Add to this mix the growing role of foreign R&D centers and the increasing number of returnees, especially in such fields as life science and biotechnology, and it can be said that the innovation landscape in China may be poised for a dramatic change in the center of gravity. Will it lead to a substantially more innovative China, only time will tell? Of course, China is not yet ready to abandon reliance on strong statist-led initiatives to drive key S&T advance. Still, one thing appears to be very clear, namely that necessity of enhancing innovative performance combined with a renewed inclination to clean up some of the burdensome bureaucratic problems inherent in the existing S&T system seems to have unleashed a new willingness to experiment and breakdown existing sacred cows across the entire S&T machinery in China.

China's Most Innovative Firms 2011			
Rank	**Name of Company**	**Business Sector**	**R&D Spending %**
1	Huawei Technologies Co., Ltd	Information and Communications Technology (ICT)	8.94%
2	Baidu, Inc	Internet Search	9.07%
3	Tencent QQ	Instant Messaging	8.58%
4	Semiconductor Manufacturing International Corporation (SMIC)	Semiconductor	11.25%
5	Ctrip.com International Ltd. (CTRP)	Internet Travel Service	15.75%
6	ZTE Corporation	Information and Communications Technology (ICT)	10.09%
7	Sohu.com, Inc.	Internet Information Provider	12.34%
8	NetEase	Internet Information Provider	5.62%
9	Lenovo Group Limited	Computer Hardware, Computer System, Electronics	1.28%

10	INSIGMA Technology Company Ltd	Computer Software	1.18%
11	Yulong Computer Telecommunication Scientific (Shenzhen) Co., Ltd.	Telecommunication	1.55%
12	Laibao Hi-Tech Co., Ltd.	Electronic Devices/Display Tech	3.97%
13	China Merchants Bank, CMB	Banking	N/A
14	BYD Auto Co., Ltd.	Automobiles	3.01%
15	Great Wall Motors Company Limited	Automobiles	2.02%
16	Haier Group	Home Appliances, Consumer Electronics	6.00%
17	Ping'an Insurance	Insurance	N/A
18	China Vanke	Real Estate	N/A
19	Mindray Medical International Limited	Medical Devices	8.56%
20	SAIC Motor Corporation Limited	Automobiles	1.21%

Sources: *Manager*, 2011, Issue 6; http://www.sino-manager.com; www.haier.com.cn.
China's Top Innovative Companies—2012 (Fast Company)

Tencent	Internet company with over 700 million users, $3 billion in revenue, and $1 billion in profits. QQ mobile and gaming.
Greenbox	Children's clothing fashion brand, emphasizing quality and safety.
United Styles	Shanghai based company that lets users design, order, share and preview their own clothing on line. Garments produced by Chinese digital textile printers.
Lenovo	China's first real global brand, PRC's top PC maker known for speed, quality and innovation in IT product space.
Suntech Power	Producer of solar energy equipment that has gone global with growing sales to India and has manufacturing in the US.
Renren	Largest real-name social network site in China. Gone beyond being Facebook clone to own identity.
BYD	First firm in China to bring electric to public transportation with creation of world's first purely electric bus. Exploring advances in battery

	technology to support clean-energy cars.
Innovation Works	Provides coaching and funding to support early stage start-ups in China. Key player in helping grow technology entrepreneurship in Chinese market.
Alibaba	First serious e-Commerce player in Chinese market. Has introduced AliCloud to support new offerings, including K-Touch Cloud-Smart Phone.
Huawei	Dynamic telecommunications equipment firm that heavily invests in R&D and has established R&D centers across the globe. Has provided core telecom equipment across Africa/Middle East.

Source: Fast Company (magazine), 2012 (www.fastcompany.com/most-innovative-companies/2012/industry/china)

PANEL II: QUESTION & ANSWER

CHAIRMAN SHEA: Well, thank you very much, both of you, for your testimony.

I'll take the first question. There was a lot of discussion about the 12th Five Year Plan. One of the goals of the plan, as I understand it, is to set a direction where China moves more away from an export-led, investment-oriented economy towards one focused more on domestic consumption. There is debate as to whether that's, in fact, occurring or even possible to occur.

You see the World Bank report recently authored in conjunction with a Chinese think tank urging for limitations on the state-oriented sector, including Chinese state banks, which lend predominantly to state enterprises.

If China were to head in the direction of a more domestically oriented economy, if there was less dominance of the state sector, both in finance and in the industrial sector, what prospects would that have for innovation in China?

DR. D. SIMON: I think that what we would see is an unleashing of a set of entrepreneurial energies, particularly at the local level, that in some places simply have been pent up. I just was with the mayor of Wuxi, who was a participant in the Innovation Dialogue, and he described a situation that goes back not only dozens of years, but hundreds of years, in which Wuxi had been playing this very entrepreneurial role in the Chinese economy, and given a number of changes that he's been able to bring about, he basically talks about, in a sense, a new wave of not only innovation but a new wave of entrepreneurship that seems to be taking hold.

We have a number of other cities where that's happening at the local level. We see in China, for example, for the first time, I think this past year, 2010, that more than 50 percent of the allocation of monies for science and technology advance is now coming from local governments versus the central government.

So we see this transition. As decentralization moves ahead, the role of the central government is almost necessarily going to decline, and I think that bodes well for innovative performance in China.

DR. SUTTMEIER: One reason for mentioning some of these drivers, especially the urbanization piece and the environment resource piece, is I think the fact that these are now elevated to important objectives in the national R&D and innovation policies, which indicates much more focus, much more investment in those sectors and the whole set of possible technologies that will surround those, from transportation, communication, health care, et cetera.

So there is a lot of interesting discussion going on about how you can take this urbanization phenomenon, which is a very big issue in China, and give it an innovative spin, if you will, and in a certain sense have it be a driver.

So the question of redirecting the economy is a much bigger issue, but in terms of your question, in terms of the effect on the innovation system, I think there are some new targets. It's not only export industries; it's not only manufacturing. It's now a set of social demands where China is going to be trying to bring together technological capabilities in energy, as I said, transport, and a whole series of things.

CHAIRMAN SHEA: Around consumption?

DR. SUTTMEIER: Around consumption, exactly.

CHAIRMAN SHEA: Right.

DR. SUTTMEIER: Yeah, yeah.

CHAIRMAN SHEA: One thing when we were in China last --this remark by an American representative of an American high-tech company sort of stuck with me. He said that in the United States, if a student of a Nobel Prize winning scientist overturns that scientist's theory, comes up with a new theory that completely devastates his mentor's theory, that student is rewarded. And in China, a Chinese student would never try to come up with a theory that would undermine his or her mentor's theory.

It sort of struck me. I was just wondering if you could comment on that?

DR. SUTTMEIER: I think there is an element of truth to that. I mean that goes back to underlying Confucian pedagogy that still is very characteristic of a lot of what happens in Chinese universities.

Of course, you could also add that maybe the first question is for China to win the Nobel Prize.

CHAIRMAN SHEA: Well, they have on the peace side, but--

DR. SUTTMEIER: Well, that's right. But, and they have in the sciences, of course, but not scientists working in China. One of our colleagues and collaborators has written an interesting piece on China's struggle to get a Nobel Prize in the sciences.

DR. D. SIMON: I think I agree with Pete, but actually if you look at the top ten universities in China, those universities have been selected with a special mission and that is to become world-class universities. If you look inside the bowels of those universities, you see increasingly larger and larger numbers of Western-trained faculty members. Those faculty members, I think, coming back, even though there is a certain amount of linkage back to Chinese culture and that pedagogy, I think they understand that progress will only come from that kind of challenging learning environment.

So I think we're at the beginning of a change. Now whether or not that will move down past those top ten or 15 universities, down to the lower echelon universities, second tier and third tier universities, that's a big question for China.

Unlike the United States where we can go through the first top 100 universities and still get a very good education, in China, the drop-off after the first 15 or 20 is really sharp, and we probably won't see that kind of innovative pedagogy introduced very quickly over the next coming years.

CHAIRMAN SHEA: Thank you very much.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you, gentlemen, for being here, and again a very interesting panel and very interesting subject today.

I'm trying to understand some of this --I'm trying to understand all of it, I should say. And Dr. Simon, I appreciate your comparison with the 11th and 12th Five Year Plans. I think that was very helpful.

Despite saying that it doesn't want to be an export-led economy, China in fact has their exports to the U.S. and the trade deficit this morning up ten percent over the previous month, so I don't know that that model has yet changed.

But everyone is talking about the need for China to consume more domestically. And I think there are certainly many advantages to that, but let's look at it from the question of innovation, which is your expertise. If you look at aerospace, China wants to be more self-sufficient.

I don't know that they'll ever get-- they're going to be at the 747, 787 Dreamliner situation in a couple of years, but with the ARJ21, the C919, et cetera,

they've made pretty substantial leaps over the last couple of years. They've learned how to integrate and with GE's avionics relationship with them, they'll probably move up the food chain.

In autos, they've become close to world-class producers. Their market is relatively closed. 18 million consumers bought cars last year. The U.S. was only able to get 106,000 vehicles into that market. Average price of 37, $38,000. So their domestic consumption is being fueled domestically.

If you look at telecom, same thing. Huawei, ZTE, China Telecom, you go across the board.

So their indigenous innovation, the movement of foreign R&D to China, and often the integration of innovation and production, that relationship -- is China becoming more, along the models they're going on now, becoming more consumer or more domestic consumption oriented? Isn't that really creating a safe harbor now for the next couple of years for China to, in fact, accelerate their innovation to the exclusion of other international players? Unless you move there, unless you move your R&D there, and what we had hoped is that their consumption patterns would open their market up to foreign suppliers.

We find now, just like Japan did in the '80s, it's a sanctuary market. Am I wrong? I mean how do you look at this? Both of you, please.

DR. D. SIMON: If you look at what's happening, let's take the market for luxury goods, China now is the largest consumer, you name the luxury product, including Rolls Royce, et cetera, and the major car companies are even designing special versions of well-known cars just simply for the China market because the demand is so huge, and it continues to grow.

What you also have to remember is that we've just gone through basically the first 600 million people along coastal China and part of the middle of China. We still haven't penetrated way back into the western part of the country, and we still have another 600, 700 million people to go in terms of filling and being able to have the kind of consumption patterns that exist on the coast and that will take awhile for it to happen, if it does happen.

But that's a great growth potential, everything from white goods and some of the basic infrastructure products to some of these luxury goods. So the growth potential is there. Chinese firms don't seem to be able to occupy that space and don't seem to be able to fill that market demand for those kinds of products right--

COMMISSIONER WESSEL: But well,, we've looked at Whirlpool and Maytag and others that have shut down here.

DR. D. SIMON: Right.

COMMISSIONER WESSEL: Moved to Mexico or elsewhere. Haier is an indigenous brand, which actually has some brand prestige in China and somewhat around the world. Are we moving from export-led to import protection?

DR. D. SIMON: Substitution.

COMMISSIONER WESSEL: Substitution in that the innovation, that this market and the consumption pattern change isn't going to do anything for us, and may, in fact, accelerate their domestic innovation.

DR. D. SIMON: Okay. So don't forget there are two parts to this.

COMMISSIONER WESSEL: Because I don't look at a Versace--

DR. D. SIMON: Yeah. Well, no. And we don't--

COMMISSIONER WESSEL: --whatever Versace makes. I don't look at that as a tremendous amount of innovation.

DR. D. SIMON: No. But if you look at the two sides of this movement of our firms over to China, sure, there is the job side, and I don't want to diminish the importance of that dimension of it. But don't forget, our firms are now setting up huge operations in China. Before they set them up in China as an export platform; now they're setting them up primarily to address Chinese domestic consumption and growth--Ford, Intel, you name the company in the famous U.S. Fortune 500 companies, they now have significant operations in China and continue to grow.

The R&D they're bringing over is designed to make products more compatible, at first brush, for the Chinese marketplace. And then you have to ask yourself the question, where did the profits accrue for those companies that are setting up operations there? So when GM sells a car in China, sure, it hasn't been made here in Detroit or somewhere in that vicinity, but it's still accruing profits. Those profits do make their way back to the United States and should make their way back to the American economy.

Part of the problem that Danny and Rob talked about was that U.S. companies have these huge war chests of money that they're not taking and plowing back into the economy here. If anywhere, they're putting them back into growth opportunities in the emerging markets, China, India and elsewhere, and that's a big problem.

So it's not so much that China is closed. It's that the recycling of those dollars that even our companies earn are not making their way back into the United States in terms of renewed investment in our economy.

CHAIRMAN SHEA: Commissioner--

COMMISSIONER WESSEL: I think, Mr. Suttmeier--a quick response if that's okay.

DR. SUTTMEIER: Thank you.

I would just add two things. I think one is that the comparison with Japan is not quite right because China is clearly open to foreign investment in ways that were never the case in Japan, so just driving around in traffic jams in Beijing, you're not seeing all that many Chinese branded vehicles, but you're seeing it from all over the world, which was never true in Tokyo.

Secondly, I think there is this whole question of repatriation and the larger issue of the impacts of all this on the U.S. economy. But I think it's, in part, because of the strength of foreign presence in China and their ability to capture value from high-end production that is very much behind the whole indigenous innovation strategy.

So I think what China is trying to do is to say we want a bigger piece of that pie, and the way we do it is to come, somehow develop our own intellectual property, to begin to take patents, to begin to set standards, and so forth and so on.

So I mean whether that's smart or not smart, I think that's part of their thinking of the whole thing.

COMMISSIONER WESSEL: Thank you.

CHAIRMAN SHEA: Commissioner D'Amato.

COMMISSIONER D'AMATO: Thank you, Mr. Chairman, and thank you both for your testimony.

It's very interesting, these trends that are shifting and trying to assess

them. I'm very interested in your description of the article by Wen in the Communist publication there because he has been, of course, outspoken and is a progressive, and is a powerful figure. The question is whether he's a lone voice in the wilderness, and what happens when he goes?

To what extent, and that's what I'm interested in, to what extent do you see evidence on the part of the new leadership in terms of shifting away from the SOEs toward more smaller businesses, even foreign businesses, to develop their innovative capacities?

That would be interesting to me because it would be a shift at a time when it's delicate for them, and there's leadership change, and it would be quite interesting if we could actually find evidence of that. That's the first part.

The second part is to what extent are foreign financial institutions going to take a role here other than Chinese financial institutions -- foreign financial institutions that help to develop small and medium firm entrepreneurship outside the SOE orbit, and is that going to be a driver here? Do you see that as a driver here?

Both of you, please.

DR. D. SIMON: I have to remember the first question.

COMMISSIONER D'AMATO: What evidence in the new leadership--

DR. D. SIMON: Okay. Yes. One of the advantages that Pete and I have, we've spent probably together about over 60 years of time studying Chinese S&T, is that we spend a lot of time talking to people in think tanks. Those are the places where policy advice comes from, where policy is actually made in some ways. If you look at the think tanks in China, particularly those under the Ministry of Science and Technology and a number of other think tanks, one, the Development Research Center at the State Council, you begin to see projects underway that are actually looking very seriously at all of these transitional issues that I've raised.

Even on one of the visits that we had with the Innovation Dialogue Experts Group, we had basically a storyline presented to us that literally described the need to transition to these small and medium enterprises.

In fact, one of the positive sides of this dialogue is actually the frank exchange that we actually do have offline where the government people aren't necessarily in the room, and the experts actually do get a chance to really trade their expertise with one another.

But I really do see , in many ways, that this is becoming more and more real, and my sense is that barring some particularly difficult moment for the Chinese economy, I think that these transitions are already underway as we speak.

In terms of the foreign financial institutions, one thing is very clear, that Western venture capital has swarmed all over China. In fact, it's a little bit of a sad story. We brought the Chinese counterpart expert delegation to the United States to visit Silicon Valley, and to a person, and this was somewhat upsetting to both the U.S. government people and the experts on the U.S. side, was that the venture capital people in Silicon Valley said if they have a dollar to invest, that that dollar would go to China rather than in the United States.

They described a litany of problems and difficulties in terms of environmental regulation and other kinds of red tape that basically made it much easier for them to bring that dollar to China and find some emerging Chinese company than it was to put that dollar in the United States.

To all of us, that was a rather distressing message. We expected them to say something like well, China's IPR laws are no good. We won't put money there until you improve your IPR. It was just the opposite message.

DR. SUTTMEIER: Just on the question of the SOEs, in a certain sense your question goes to the very delicate elite political struggles now going on.

There is a question of, that part of the preferences SOEs have, as I think you know because you've had hearings on it, has a lot to do with the fact that the political leaders and their families are so invested in them. That said, I think there is at the same time recognition of the importance of doing something with the non-SOE parts of the system, which are in many ways quite robust. I mean as Dan Breznitz's work illustrates, there's a lot going on out there. But still, I think the policy preferences and, in particular, finance, but other policies as well, have been so biased towards the SOEs, that the others have had a problem.

And I think that Denis is right that there are signs now that that's beginning to change, but it does not necessarily mean that it's a zero sum game and that the SOEs will lose because I think politically there is so much invested in them, that it's a little bit difficult to get them out of the game.

Interestingly, I think something of concern would be the extent to which, if you have a more robust non-SOE sector, the extent to which they then generate competition for the SOEs and actually maybe make the SOEs more innovative in the process, and that could be, through things like supplier relationships , where you're going to have non-SOEs doing very high-tech kinds of work, that are then going to be supplying the SOEs as well.

COMMISSIONER D'AMATO: Thank you.

CHAIRMAN SHEA: Commissioner Cleveland.

COMMISSIONER CLEVELAND: Actually Commissioner D'Amato got at a piece of an issue that I'm interested in, which is what is the evidence other than what you've learned at think tanks of this emerging role? One of you, I think Mr. Suttmeier, you talked about the fact that there was this entrepreneurial energy, and Dr. Simon, you said that there were catalytic engines.

Is it just an emphasis at this point or is there evidence in terms of, I think, Dr. Simon, you mentioned in your oral testimony that 50 percent of local financing is going to SMEs? I'm interested in how much financing that is compared to, say, state-owned enterprise subsidies?

And if, in fact, it is, we move in this direction, what would you see as the benchmarks or evidence in the next year or two that the SMEs are emerging as a credible element of economic growth? And do you anticipate that their markets will be domestic or that they'll emerge on the international scene as an element of growth?

DR. D. SIMON: I think you simply have to, in some cases, look at the tea leaves. I mean part of the field of Sinology is making some educated guesses about what's going on. But even more important, what you hear from people to whom we've been talking for a long time is a clear change in the tone of their emphasis about where they think the locus of innovation is going to come from.

And in doing that, don't forget, one of the most powerful organizations in China is this State Administration for Asset Control, SASAC, which basically oversees the state-owned enterprises and provides a tremendous amount of the push behind the money and effort that goes to keep them vibrant and keep them going at the level that

they are.

But now we're seeing alternative monies coming in terms of these local government S&T expenditures that are going to more of the local companies in these provinces and municipalities that I think bodes well for the fact that we're seeing what I would call a more complex industrial structure emerge in China. That that industrial structure is starting to replicate more and more the kind of advanced industrial structure that we find in some Western countries where you're going to have these same kind of domestic supply chains, and, in fact, if innovation--I think of the work of Eric Von Hippel and some other people at MIT, where basically you look at the role of supplier companies as providing ideas and sources of new knowledge into the larger parent companies.

So when you think about our big pharma companies, our big chemical companies, a lot of the new drug development and new chemical development comes from these smaller and medium companies all around the United States. We're starting to see those relationships also emerge in China, and we're starting to see a kind of connectivity there that wasn't there before, and that's why these platforms and this collaborative R&D, and the kinds of things--the messaging, in other words, is beginning to change, and the reason why I wanted to discuss what I did was because I think we're on the cusp of this kind of change.

Will it come to completion? I think the fact that we see people like Bo Xilai being pushed on suggests that, in fact, we probably will get, even though it will be tense, and it will be stressful, et cetera, I think we are moving in the direction that suggests that the industrial structure will become a richer, more complex, more diversified structure that hopefully will be more innovation driven.

I think the Chinese have to succeed. In some ways they can't afford not to succeed in making this happen. They can't any longer depend on a fossil fuel burning, resource consuming, environmentally damaging model of economic development.

It's not only the World Bank that tells them; it's not only foreigners that tell them. Their own people inside the country are telling them this, and so they understand that they've got to move away from the current model with its emphasis on state-driven economic and technological development.

DR. SUTTMEIER: Just to clarify, that 50 percent figure, that should be understood as the local governments now, in terms of national expenditures on R&D; local governments are now spending 50 percent of what the national government is doing. Right.

DR. D. SIMON: Ten years ago, 60 percent, 60 plus percent of the monies for R&D spending were coming from the central government. Somewhat near 40 percent was coming from local government. That has now transitioned to over 50 percent coming from local governments. Local governments are supplying those monies to local enterprises in their jurisdictions in order to support their R&D efforts.

So that means that the central government before probably was not giving money to these small and medium enterprises; they were probably feeding into these larger project-driven SOE projects rather than the small vibrant SMEs. They were trying to get the money closer to where the research happens, and by doing that, that means the local governments now have this better linkage with the smaller firms in their domain.

DR. SUTTMEIER: Thank you.

[Laughter.]

DR. D. SIMON: Well, I'm sorry. Well, I--

DR. SUTTMEIER: No, I think there is something about this local ecosystem phenomenon that's really quite important, and it's not a simple matter of state-owned enterprise versus not state-owned because some of the enterprises that would be supported by local governments will be state owned. They may very well be local-government owned, for instance. But I think what you're really seeing is, as Denis was suggesting, a kind of growing mixture and differentiation of types of activities.

So, for instance, what you would typically see is local governments, for instance, putting up funds to support an institute from the Chinese Academy of Sciences to locate a facility in that jurisdiction. That would then be combined with incentive monies for a returnee, of somebody who has a Ph.D., maybe some industrial experience from the United States, to go back and take advantage of some policy preferences in that jurisdiction, which now has, as well, a new research center that's linked with the national research center.

So it's a variety of things that are interacting. I mean one value of Danny Breznitz's notion of structured uncertainty is that he captures this sense that you can't look at an organization chart and get a simple understanding of what it is. There's a whole series of relationships that bring these institutions together in a legal framework in some cases, but in an extralegal framework in other cases, as well.

CHAIRMAN SHEA: Commissioner Slane.

COMMISSIONER SLANE: Thank you. Thank you, both, for taking the time to come.

Several economists that I have been following said that it may take the Chinese 20 or 30 years before they are able to innovate. We heard this morning that what they really are very good at is modifying existing innovation. And given their culture and their educational system, and the SOEs and the lack of intellectual property and all these other issues, do you agree that it's going to take 20 or 30 years before they're able to develop their own innovation?

DR. SUTTMEIER: This question that I sort of alluded to in my written--it seems to me that at this point, we really have to be far more discriminating about what we mean by innovation. So what we heard in the first panel was the sort of notion of discontinuous innovation, and I think in many ways, that is true, that China has lagged a bit behind that.

But certainly you see a whole variety of innovative activities going on all the time now in China, and it's the secondary innovation they were talking about, business model innovation, as a lot of people have commented on, and so forth.

Lots of things are happening, so I think to say that it'll be 20 years before China is innovative is really very misleading. Twenty years before it starts producing world-class products or new blockbuster products, perhaps, but then you have to look a little bit at some of the things that happened in terms of supercomputing, in terms of more specialized technologies, including space, defense related stuff, and so forth.

So I think there is, to simply say 20 years before anything happens is really kind of misleading. It's sort of the wrong way to phrase the question, I would say, because you have to be much more discriminating about what kind of innovation you're talking about.

DR. D. SIMON: In my written testimony, I attached a list that was produced

by Fast Company, a magazine which talks about cutting edge technology in the United States, and every year they look at the world's most innovative companies, and they actually put together a list of what they thought were China's ten most innovative companies.

Eight of the ten on the list are non-state-owned enterprises. And they range from Tencent, which is an Internet company, Greenbox, which makes children's clothing, United Styles, which lets users design their own clothing, and on down to Alibaba, Innovation Works, and BYD. So if you ride a bus at LAX now, it's going to be the first electric bus designed by a company. That company was BYD, the Chinese company who made those buses.

So are we seeing China at the cutting edge of the frontier in a lot of these things? I think that it's a process of getting there, but I think one of the things that China sees is this notion of walking on two legs. I think they're very cautious not to mistake indigenous innovation for self-reliance, and I think we have to keep remembering that.

The notion of self-reliance that was very prevalent in China in the '60s and '70s is not the notion of indigenous innovation that we're talking about today.

Indigenous innovation means the ability of China to claim or basically own some of that intellectual property that goes into the making of world-class products, and I think the Chinese are anxious that they are not sitting on the margins or on the sidelines of all this innovation that's taking place, and therefore if we look at the formation of innovation networks and collaborative R&D across borders, across the global economy, increasingly we're seeing Chinese companies be part of those networks, and therefore this 20 or 30 year gestation period I think is probably exaggerated.

I think that we're going to see a much higher performing Chinese innovation system within the next five to ten years if the things I talked about start to kick in.

COMMISSIONER SLANE: Thank you.

CHAIRMAN SHEA: Commissioner Bartholomew.

COMMISSIONER BARTHOLOMEW: Thanks very much, and thank you, gentlemen. Interesting testimony.

A couple of things. One is, several years, more like seven or eight years ago, we had a hearing out in Silicon Valley, and former Secretary Perry testified, and one of the challenges he was talking about was the fact that so much research is now done with product in mind, and that we need an emphasis on basic research to be taking place instead of just productivizing what's happening at the other end, and he really saw that then as a weakness in the system that we have.

But I want to tie that to Chinese scientists and engineers who are being trained in the United States. Do we have any idea where they're going back to? Are they going into the private sector? Are they going primarily to SOEs? Are they going to universities? Are they going to these think tanks that you're talking about?

DR. SUTTMEIER: Yes, I think we were actually both at that hearing also at that time. It was a very interesting session.

COMMISSIONER BARTHOLOMEW: Yeah, yeah. Gosh, it was a long time ago, wasn't it?

DR. SUTTMEIER: Yes.

COMMISSIONER BARTHOLOMEW: We were a lot younger then.

DR. SUTTMEIER: But we have some idea, I think. I think it's fair to say that it's a developmental kind of phenomenon. If you look ten years ago, most people would go back into universities or perhaps something like the Chinese Academy of Sciences. Starting maybe eight, nine years ago, we begin to see them going back and maybe starting companies.

I think that there is some indication now that some of them are actually going to be going into SOEs as well. That's been a problem, going back to Commissioner Cleveland's question about the evidence for what's happening outside of the SOE.

I mean there is work being done by Chinese scholars that has been looking at that question and has demonstrated that if you look at the intensity of R&D in the non-state sector, it's greater personnel. There's more attention to recruiting people with high-level training.

There is, very recently, though, some more attention being given to getting these people back--getting them into the SOEs as well. They can pay quite generously at this point, and in some cases, in the petrochemical industry, for instance, there's some very sophisticated work that goes on. So professionally it would be challenging as well.

COMMISSIONER BARTHOLOMEW: Obviously, becoming an innovation society is really also going to be dependent on universities, and the people who are going back in there, and I'm wondering about the culture that they are exposed to here, and the culture to which they are going back, and how people are dealing with that? I mean what's the state of academic freedom in Chinese universities? And academic scientists and engineers like to go where their ideas take them. Do they have the ability to do that, or are they being slotted into we expect you to focus on this and this kind of end-product?

DR. D. SIMON: I think that what's happening is that there's an intensive recruitment effort at two levels. One, there is a program called the 1,000 Talents Program that's sponsored by the Organization Department of the Party, led by Minister Li Yuanchao. Those are the elite. I mean the Chinese are looking for the best of the best.

Now whether or not the best of the best are going back, that's a very mixed question. The general conclusion, I think our colleague Cao Cong would say is that, no, the best aren't going back.

But it's not just salary. In fact, what you find is that given the $3 trillion that China has in foreign exchange reserves, et cetera, actually there's a leveling of salary, and in fact some institutions are making it extremely attractive for these people to want to go back.

So there's something else that's inhibiting it because they get a good lab, they get good equipment, and they get a lot of perks when they go back, but they encounter two big problems. One is just simply petty jealousies, people who have toiled for five or ten years and are looking at this favorite son coming back and getting a lot of preferential treatment. That's creating some biases and problems in terms of the gelling of these teams.

But the other problem is that periodically, as we see when there are political crackdowns, when there are changes in the political environment that are not very welcome, I think a lot of people give a second thought to the idea of going back.

The other problem is that many of them are striking deals. We see a lot of people with a foot in a university in the United States, and another foot in a university or a think tank or a lab in China, and there is just a host of people now who are doing that, in a sense, able to leverage both their job here in the United States and also the opportunity to work with graduate students and colleagues in China all at the same time and also get funding for their research in China.

And I think that's creating the very interesting mix in terms of the linkage between our scientific community and the Chinese scientific community.

DR. SUTTMEIER: If I might just follow up just a little bit, going back to Bill Perry's question about the basic research. I think this is a very interesting question right now. If you look at expenditures on basic research in China, you'll see that they go up very rapidly.

But in terms of the overall share of basic research in the national R&D account, it's still marginal. In fact, it's gone down a little bit. Overwhelmingly, this national R&D effort is in development, not even applied research. It's in development.

But on the other hand, you then look at these aspirations that China has, the 12th Plan and strategic emerging industries, et cetera, and they are all for leapfrogging into new science-based industries for which basic research is going to be very important.

So then the question becomes what is that culture, and I think you're absolutely right to call attention to it. I think there are real problems within the universities at this point, having to do with the way they're managed and whether they can really perform up to world standards in really creative basic research, and then the Academy of Sciences as well.

So you see an interesting thing going on in the Academy, where in many ways they are doing a lot of basic research, but they're a little bit confused about their mission. Should they be doing mainly basic research? The new president I think seems to think that a little bit more. Or should they be doing work that serves national need? The old president had a little bit of sense of that.

So if you want to start moving into basic research, how do you begin to tweak the whole management system so that you're now stimulating creativity as opposed to meeting plan targets? I think that's a very interesting challenge that they face right now.

COMMISSIONER BARTHOLOMEW: I would just point out that balancing some of those challenges, while it's completely different in China -- there was a very interesting article recently about Stanford and Silicon Valley, and whether Stanford is too close to Silicon Valley in terms of just being able to think without it -- there is the issue of how do we turn what we're thinking into something that makes money?

DR. D. SIMON: One quick comment. The China National Natural Science Foundation just had a major international review that I would recommend to the committee members. It's both available in Chinese and in English on their Web site, and they commissioned a group of international experts to come together and review the performance of that foundation in terms of supporting basic research and the kind of activities in which its engaged in terms of how it funds particular projects, how it reviews those projects, et cetera.

It's a very illuminating report that I think would be very useful to the committee members after this hearing.

CHAIRMAN SHEA: Thank you.

DR. SUTTMEIER: One more. I guess basic research is hot. One of the interesting questions--you know, the Chinese in so many documents and so much public discourse always talk about "keji." "Keji" is "kexue," science; "jishu," technology. So they collapsed them together, "keji," and I think there is a feeling now among some people that that's a big mistake. Because it leads then to this overwhelming attention to technological development and, you know, undermines the attention to science.

And I think there's a little bit of the same problem in the United States. We stopped talking about science policy, and perhaps we should. I mean we should perhaps begin to start thinking a little bit about what is science, and what is good science and basic science, and what does it mean for society? I think the Chinese are struggling with that a little bit now, too.

CHAIRMAN SHEA: We have three more questions on the second round unless anyone else wants to dive in. I'll take the first question and work off Carolyn's, Commissioner Bartholomew's, statement about location between Stanford and Silicon Valley.

Dr. Breznitz in his book says that Chinese innovation is very geographically concentrated, in Beijing, Shanghai, and the Pearl River Delta area, and I was wondering, do you agree with that? Is that a good thing? Is it a bad thing? Do you see any other areas within China becoming centers of innovative activity?

DR. SUTTMEIER: Yes.

CHAIRMAN SHEA: To all those questions?

DR. SUTTMEIER: That's right.

[Laughter.]

DR. SUTTMEIER: I think their study was focused on ICT and much more commercial technology, but if you begin to look at the distribution of industry and research institutions, they're far more widespread than that. For instance, a place like Changchun has a very fine institute for optics, and they do work for the space program, they do work for all kinds of stuff. They sell their stuff internationally, and it's very good stuff.

You can look at a place like Wuhan. Sichuan has a lot of defense industries. So there is a lot more going on. The whole province of Jiangsu, which has become the center for a lot of the SME non-state activity. I think to only look at those three, very understandable given their research design, is to miss the bigger picture, especially as you begin to move out of an ICT-focused view of innovation. I mean that's another important thing to keep in mind because, as we begin to move into energy and nanotechnology materials, we shouldn't always be locked in with the ICT paradigm, if you will.

CHAIRMAN SHEA: Thank you.

Dr. Simon.

DR. D. SIMON: Somebody asked before is there is a good book to read about the Chinese scientific and engineering community, and actually Cao Cong and I did a book about two years ago called China's Emerging Technological Age, which looks at these issues, and one of the issues we looked at was the distribution of scientific and engineering talent, and indeed, it is the case that those three locations are the main three hubs, and in fact, when you talk to people, and we talked to, whether it's a foreign company like Intel up in Dalian, or you talk to a domestic company that's out in

Chengdu, they do have a rather difficult time luring talent away from the coastal areas.

And so while the Chinese government, in effect, is saying to everyone go west, we'd like to see the interior of the economy develop, the reality is that the distribution of talent continues to move east, and that is a major problem for the society as they look ahead.

Nonetheless, I think Pete is exactly right. We do see these hubs. I was just in Wuhan and actually visiting the optoelectronics valley where they're developing lasers and all sorts of other advanced technology in that area, and I mean they are no slouches in terms of what's there.

So I think Pete's caution is correct. When you just take this ICT look at China, you get a very narrow picture, and the country does have a broader array, and should China have a critical mass in those three hubs, and pin all their efforts just on those three cities as their big launch pins for science and technology, I think they've decided that that's not what they're going to do.

So I think that this distribution is something they just have to work out using the market and labor markets because they don't have that labor allocation system that they once did to correct those problems.

CHAIRMAN SHEA: Okay. Great. Thank you, Doctor.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you, gentlemen, again.

I'd like to springboard off of some of the questions about the students, et cetera, and understand, if I can, from both your bilateral exchanges as well as your work with our own government, OSTP, et cetera.

When a Chinese entity, whatever, SME, SOE, et cetera, is looking for an asset, how much government involvement is that, meaning are they tracking their students here, their development, their expertise, et cetera, their niche? I mean, you know, I hate to say when I think of a U.S. company, I don't think, well, you know, we need somebody, and I know the student over inBrazil who is the right guy. That seems to be a pretty good asset management plan, shall we say, number one.

Number two, polymer research is one of the limits in the Chinese innovation area, and they recently signed a fairly major agreement with a Ohio University to invest and be able to send their students there as well as collect the research. Are we as a government assessing where other similar investments may be taking place at U.S. universities to, first of all, understand what gaps there may be in Chinese innovation, as well as what risks that may pose? For both witnesses, please.

DR. D. SIMON: I think the last question is a great question. In fact, I was with the Undersecretary of Education as part of these dialogues that were held last week, and she asked me what I thought was needed, and I said I think we need an assessment or an evaluation of the impact and the spread of these educational exchanges because we've accumulated them now over 30 years, and the last time we actually took a really close look at them was about 25 years ago.

So they've spread rather rapidly, and, in fact, one of the things we often say is that these exchanges are the positive side of the relationship so that even when we have a difficult moment, the fact that we continue to collaborate in science, technology, engineering, helps to maintain and sustain the relationship over these rather difficult time periods.

So they're important. I'd say that today what you see standing outside of

the gate of any major U.S. university isthree groups. One is you see U.S. multinationals with operations in China looking for Chinese graduates to attract them to come back, and that's not small number of recruiters that are there.

You're seeing individual companies, individual Chinese companies, so for example, Huawei and companies of that sort are there, and then you're seeing local government agencies from China representing provincial interests and representing municipal interests who come periodically to the United States, en masse, stop in four or five key cities where they know that there are large Chinese student populations, and make their pitch, come on back to X.

COMMISSIONER WESSEL: So almost like a jobs fair.

DR. D. SIMON: It's like a jobs fair, and some of them are covered under these programs like the 1,000 Talent Program, or the 100s Talent Program, or whatever may be the case, but there is a massive recruitment effort to bring Chinese students back.

And you know what the debate is in the United States. Some people argue that every time a Chinese student comes here, in the left hand, we give them a Ph.D.; in the right hand, we ought to give them a green card. And other people say no, we have global talent mobility and that we should allow these people to free flow.

What China has done now most recently is they've gone from having a 1,000 Talent Program focused on ethnic Chinese now to having a 1,000 Talent Program focused also on foreign talent. So if you or I or somebody else coming from the United States who is not ethnic Chinese would like to go work in China for five years or whatever might be the case, they can put together a very attractive offer for us to go back and work as an engineer or work as a scientist in a laboratory with a lot of freedom and a lot of good equipment, and so that's becoming now part of the effort in order to ensure that there's sufficient talent.

We still have to remember the one big thing, despite all these trainees, despite all the graduates coming out of Chinese universities, the kind of talent with the kind of skills is still in short supply in China. We have talent wars going on in China rather than just, you know, while we have a surplus of graduates, we have talent wars for the best talent, and that's why people are reaching back into the United States, Europe, Australia, elsewhere, to bring some of this labor force back.

COMMISSIONER WESSEL: Thank you.

CHAIRMAN SHEA: Commissioner Cleveland. Oh.

DR. SUTTMEIER: I just wanted to pick up one thing, Commissioner Wessel, the question you put to Rob Atkinson about the Wolf initiative and NASA and OSTP and so forth.

One of the things that I think requires a lot more attention, and it goes to some of what has just been said, is the extent to which the United States actually is set up to exploit fully the opportunities from these relationships.

I many years ago wrote the first study of U.S.-China S&T relationship, and I've been working on it a little bit since then, and I think one consistent thing is the nature of our society. We have extensive relations all through the system, through academic activities, through multinational corporations, but when it comes to really getting a sense of strategy for the nation to really take advantage of what's happening, I think we're not there, and then the question becomes is OSTP the place for that to happen, and should we really be thinking about strengthening OSTP rather than

eviscerating it in some sense.

I don't know the answer to that, but I think the question is really quite important, and I think maybe the Commission might think about that a little bit.

COMMISSIONER WESSEL: Thank you.

CHAIRMAN SHEA: Commissioner Cleveland.

COMMISSIONER CLEVELAND: Thank you.

I'm wondering, Dr. Simon, if you would be willing to give us a cheat sheet on your book and give us a profile of what kind of engineering students they're graduating because I assume that there are national kind of directives as do we need more chemical versus electrical? So I'd be interested in that.

Mr. Suttmeier, you said in your prepared testimony, I don't think you mentioned it in your oral, that between the drivers of the successful and not so successful outcomes of research and innovation, there are an array of institutions that are very diverse, and you mentioned the presence of multinational corporations, 1,300 of whom now have R&D centers in China of one sort of another.

Could you talk about the role that those multinational corporations are playing in this issue of innovation, and distinguish, if you would, between first generation versus what our earlier panel talked about of secondary?

DR. SUTTMEIER: Yeah. There are a variety of different activities going on. I think you have to recognize that everything from market adaptations, which are not terribly demanding intellectually, to world-class research in some places, and you know, there are obviously, in the latter, in particular, there's an interest in tapping into the talent pool and getting really good people that's available in China, just as we see the same thing happening in India, and we see it happening in Europe as well.

The interesting question, of course, is the extent to which you have spillovers that are really going to help the Chinese economy, and there, my own feeling is that, in fact, that's happening, but, in fact, the Chinese scholars who have looked at this have sort of taken the view that there isn't as much spillover as there might be, and that China is not getting as much out of these, the presence of these things, as they really should.

It's a big, very big question, which we could go into a little bit more. But I think, I would say that's sort of the essence of what I would say about it. Denis has looked at it also quite a lot.

DR. D. SIMON: I think the general word on the street is that companies go to China no longer for Chinese brawn, but for Chinese brains. So that's sort of the way to look at it in many ways, that, in fact, in the recent World Bank study that came out, China 2030, they talk specifically about the role of foreign R&D as performing the kind of catalytic function, particularly in terms of labor circulation.

So what will happen is that somebody will have a three-to-five year career in one of these research institutes or centers, like GE or IBM or whatever, but in China, there's a saying "I'd rather be the head of the chicken than the tail of the ox." So a lot of these people will leave and start up their own companies or start up their own research centers or whatever, and they will become the next wave of sort of technological entrepreneurship in China, and so I think that this is very, very important because it does provide the kind of spread effects that will help further stimulate R&D in China.

Your first question about the profile of what's going on in terms of the

scientific and engineering pool, it's very interesting. In Japan, if we said that the Chinese develop just in time, in China, we might say they develop just in case.

So when, in 2000, the Chinese government said we're going to decide to have a software industry and we're going to go big time into outsourcing, China created some 11, 12 special schools and colleges around the country to start to train software engineers, except there was no sort of calculator about how many they might need.

So they just continued to turn out literally hundreds and hundreds of software engineers. So now what you have in places like Dalian, where I spent a lot of time, which is Dalian is a Bangalore wannabe in China. You have the beginnings of a very solid foundation for software engineering, but you don't have that second tier and third-tier experienced project manager or team leader to take on these larger software projects.

So unlike India, where they've gotten big projects from U.S. and European companies and even Japanese companies, the Chinese basically have been able to stay almost at a very basic level doing coding, some testing, and some programming, but haven't been able to move to that next level because that don't have that tried and true project experience at that kind of level.

So if you go to Dalian, you'll see large numbers of software engineers available, but they don't have that kind of requisite experience that you want them to have to become the leaders of those kinds of projects.

CHAIRMAN SHEA: Well, Dr. Simon, Professor Suttmeier, thank you very much for your participation. We've learned a lot from you, and we're very grateful for you to be here.

We will adjourn now till 12:45. Thank you.

[Whereupon, at 12:00 noon, the hearing recessed, to reconvene at 12:50 p.m., this same day.]

PANEL III: INFORMATION AND COMMUNICATIONS TECHNOLOGY INNOVATION

HEARING CO-CHAIR GOODWIN: I want to welcome everybody back. Appreciate your giving us a couple extra minutes to get back from lunch.

After surveying China's general S&T and innovation landscape in our morning sessions, we're planning to cover this afternoon innovation in specific sectors.

First, we'll discuss China's efforts in the field of information and communications technology with a particular emphasis on supercomputing and cloud computing.

Our witnesses for this panel include Dr. Earl Joseph, Vice President of IDC's High-Performance Computing Program; Dr. Horst Simon, Deputy Director of the Lawrence Berkeley National Laboratory; and Timothy K. Harder, Director of EMC's Cloud Infrastructure Division.

Dr. Joseph advises IDC clients on competitive, managerial, technological and implementation issues for technical servers, focusing on markets in the U.S., Europe, and Asia-Pacific.

Dr. Simon has directed several divisions of the Berkeley National Laboratory and serves as co-editor of the Biannual Top 500 List, tracking the most powerful supercomputers in the world.

Mr. Harder has extensive experience in cloud computing and has helped deploy some of the largest cloud systems in the world, and has closely followed the cloud market in China since 2007.

The witnesses will each have seven minutes to provide remarks, and we'll begin with Dr. Joseph.

STATEMENT OF DR. EARL C. JOSEPH II
PROGRAM VICE PRESIDENT, IDC

DR. JOSEPH: Great. Thanks very much.

What I'd like to do is to briefly just give you a little background on IDC and what we do for a living. IDC is a corporation, private company, that has been tracking IT markets, all forms of IT markets, everything from satellite, cell phone, telephone lines, computers, for over 45 years, and we have offices in 50 countries.

In the written notes here, you have the Web site for any additional background information. A little bit more about the company is we have more than a thousand analysts around the world, and so we take it very seriously. We're very much a numerically based company, and we get our numbers from tracking what vendors sell and what buyers purchase, of course, and last year, we conducted over 360,000 surveys, to just put in perspective when I say very quantitative numbers.

Myself, I've been in the supercomputer business since 1983. I've worked for vendors like Cray, SGI, Concurrent Real Time Systems, and Sperry Univac, and my background includes working for vendors--right now, buyers, users, and government bodies. So the organization I have within IDC, we do a lot of custom research for all three of those communities.

And to give you a little background as far as my group in IDC, is we focus only on technical computers, and a technical computer is also called high performance computers, or HPC, and it's any server that's used by a scientist, engineer, analyst or others for highly computational or highly data-intensive computing. And that's the standard definition that's been around for about 30 years.

Now, the supercomputers are the higher end of that market, and over the years, the definition of supercomputers has changed frequently. We currently use the definition of any technical computer that costs more than $500,000 U.S., so anything that's more than a half million dollars or larger, used by scientists, engineers and researchers.

And so within that space, what we do is we try every quarter to track every computer sold, and so we literally are tracking every system around the world. We also maintain five-year forecasts of every category, whether it's a region, whether it's being used for bio-life science or an industry and all the various types of things.

We published over 35 research reports a year to our client base, and then we do a lot of private studies. As I mentioned, we've done a lot of studies for U.S. government. We've helped the EU develop a ten-year HPC strategy plan and right now we're helping South Korea develop a plan, too, so we do work with government users and vendors.

With that as a background, to give you perspective, the worldwide technical computing market has grown very well over the last ten years. When we had the recession in 2008, the market stumbled a little bit for one year but then came back very strong. In 2010, it exhibited ten percent growth, and then last we just completed our numbers, as 8.4 percent growth, and we're expecting about 7.3 percent growth going forward.

In the written notes, there's some charts at the back end of it that you can look at, and I'll just speak to those in general instead of the details. But in just broad perspective, the technical computing servers are roughly $10 billion a year as far as

purchases of those servers, and they contain roughly 3.3 million processors and they're packaged in about 112,000 systems.

So that gives you an idea of the yearly purchase of these technical computers. The supercomputer side of it is around 4.4 billion and about 2,800 servers. So that gives you a general idea. In the package, it also splits it out by the different manufacturing segments, government segments, academia, and also if you look at the supercomputer part of the HPC segment, I mentioned that overall technical servers grew 8.4 percent last year, supercomputers grew 25 percent last year, and what we're seeing is a major change in the technical computing market, in particular.

It used to be always spoken to as a pyramid. So you had a pyramid where you had smaller number of large machines, a fair number of medium-sized machines and a lot of small ones. The world has changed now, and on top of this pyramid, there's a lot of massive machines being purchased. We're trying to come up with a cute name for it. At the moment, we're calling it "the diamond on top of the pyramid."

But what's going on is nations around the world have recognized that supercomputers are critical to innovation, and they're critical for economic growth and jobs. As you mentioned, your big criteria for economic growth ultimately is jobs, and many nations have recognized that the major tool for that right now is supercomputers and the application of it.

In the past, a lot of countries would try to have the one largest machine. Now it's about having lots of machines for each discipline. So, for example, China has 17 different large-scale systems that they're putting in place right now.

Even countries like Russia, in my written notes, the comment: "Russia's products will no longer be competitive or of interest to potential buyers," the president of Russia stated just a couple years ago.

So with that, I'd like to spend the last few minutes just talking about China in specific. So since 2002, China has increased their supercomputer purchases six-fold overall, between six and seven-fold, as it's shown in the package here.

The charts I'm showing show U.S. versus China for all servers and then for supercomputers. Right now, China still only purchases about a fourth as many as the U.S. does. So the U.S. clearly is still the leader, but you can see in the ramp-up here, China has made major and substantial investments.

Our concerns right now are China had the world's largest machine a year ago, but then Japan came out with a machine that was three times larger. We think China will not leave that status. We actually expect China to increase the rate of spend because the competition is much more about being faster than the largest Japanese machine instead of the largest U.S. machine.

Right now, the U.S. doesn't have the first or second-largest machine in the world; it has the third. But this is a situation or environment where they'll be leapfrogging. We're expecting in June or November of this year someone in the U.S. will install a machine that's the largest machine again.

But the clear difference here is China has gone from a non-player to being one of the top leaders in a very short period of time. They also recognize that they have many shortcomings, much as our colleagues I'm sure will bring up here too. As far as human talent, the software, and the whole ecosystem to take advantage of the machines, they're still lacking.

But the Chinese, in our opinion, recognize it entirely, and they're investing

heavily in solving those problems, and we think they'll be solved gradually. You know, some sectors faster than others, but within a five-to-ten-year time period.

The other thing I want to mention is Chinese have been innovative in the HPC arena itself. They do have three major processor developments underway, and an additional two or three other ones. They're based on standard chip technologies like MIPS, ALPHA, and SPARC-based cores. So you can buy that off the shelf and then innovate around those, and that's how they design their machines.

Also, in the attachments to the package, I have included a description of that and a description of the largest machine in China, which is, in my opinion, a very innovative machine. It has custom design processors, and they interconnect. So the way the whole internals are connected are custom, plus it has many other custom features to that.

In conclusion, I'd like to then speak to what I think the U.S. should do as far as a recommendation, and my recommendation is that the U.S. needs to recognize that we are in competition, and this is a competitive war, and we really need to double our investments as quickly as we can.

So something on the order of about two billion more in purchases of supercomputers is crucial. In addition to that, a fair amount of R&D investment is needed in high performance computing or we'll fall behind quickly, and we'd also recommend that about half that investment goes into the software side.

Right now, supercomputer software dramatically lags the hardware, and the biggest shortcoming in the overall industry worldwide is the software to take advantage of the existing hardware.

If you think of a typical supercomputer, most people only get a few percent of the actual peak capability of that hardware. So if the software could get another half percent or even a percent more, you could double the performance on your code that you're running without investing anything else in hardware. So I just want to highlight that software is a real key part.

To summarize, five years ago, China basically had very few supercomputers that would ever make it on the Top 500 List. Today, they have more than Germany or France, and it's expected that within a year, China will have more supercomputers on this Top 500 List than all of Europe.

So even though they're behind the U.S., the rate of progression is very dramatic. Their largest supercomputer right now is larger than any known supercomputer in the U.S. So I think that is something that is significant. Again, they don't have the whole infrastructure.

And the third point is they are investing in 17 separate petascale systems and centers around the country to both train their engineers. I liked this morning's discussion about the engineering talent being lacking. They recognize that and they're creating new centers to try to get engineers using computers to help them do large-scale innovation, but more importantly incremental innovation.

And sorry for going over my time a little bit.

PREPARED STATEMENT OF DR. EARL C. JOSEPH II
PROGRAM VICE PRESIDENT, IDC

Testimony before the U.S. - China Economic and Security Review Commission

Date of the hearing:
Thursday, May 10, 2012
Name of the panelist:
Dr. Earl Joseph II
Panelist's title and organization:
HPC Program Vice President, IDC
Title of Hearing:
Hearing on "Assessing China's Efforts to Become an Innovation Society—A Progress Report"
Panel IV: Information and communications technology innovation
"Supercomputers, Technical Servers And Innovation"

Outline:

1. Who Is IDC
2. My Background
3. The Technical Computing Group at IDC
4. Worldwide HPC And Supercomputer Market Trends
5. China Information -- And The US Compared To China Supercomputer Trends
6. Recommendations For Our Country
7. Conclusions And Overall Assessment
8. Charts And Tables

1. Who is IDC

IDC is a market research company that tracks IT markets. We have been tracking IT markets for over 45 years, with offices in over 50 countries. Our research approach is based on strong quantitative numbers tracking and surveys -- details can be found at: www.idc.com

IDC company highlights include:

- IDC is an independent global market intelligence, events, and advisory firm for information technology, telecommunications, and consumer technology markets (ICT).
- More than 1,000 IDC analysts, including in-house statisticians and economists, provide global, regional, and local expertise on technology and industry opportunities and trends in over 110 countries.
- IDC has been delivering IT intelligence, industry analysis, market data, and strategic guidance since its 1964 founding by Patrick McGovern.
- Our multilingual, multicultural workforce surveys over 360,000 technology users and decision makers annually, delivering unrivaled coverage.

- IDC is a subsidiary of IDG, the world's leading technology media, events and research company.

2. My Background

I have previously worked for a number of computer vendors including Cray, SGI, Concurrent real-time systems, and Sperry-Univac. I have been with IDC for over 13 years, focused on technical computing including supercomputers, buyers, users and vendors. My resume and background information can be found at: www.earljoseph.info

My Ph.D. was in the management of high technology companies with related focuses in quantitative analysis, math, and engineering.

3. The Technical Computing Group at IDC

Some definitions:

- HPC = High Performance Computing = All Types of Technical servers.
- Technical Servers = computer servers sold for use by scientists, engineers, analysts and others for highly computational or data intensive computing.
- Supercomputers = technical servers that cost more than $500,000.

Within the technical computing space, we:

- Attempt to track all HPC servers sold each quarter (around the world), from all vendors. Our data structures go back over 25 years, and we maintain 5 year forecasts in many areas and for most sub-segments.
- Conduct 4 HPC User Forum meetings each year (see: www.hpcuserforum.com)
- Publish over 35 research reports each year.
- Visit all major supercomputer sites & write reports about what they are doing and what their plans are for the future. E.G. We recently visited the large sites across China and are currently writing each one as a case study.
- Assist in collaborations between buyers/users and vendors.
- Assist governments in HPC plans, strategies and directions.
- Assist buyers/users in planning and procurements.
- Conduct an HPC innovation award program every six months.
- Conduct special research studies, e.g.:
    - USG special studies
    - EU 2020 HPC leadership plan
    - EU parallel software scaling plan
    - DOE skills, talent and hiring plan
    - Automotive benchmark analysis
    - Oil/gas HPC usage comparisons
    - NCSA/NSF science underlying applications study
    - Korean HPC strategy implementation plan
    - Council on competitiveness innovation studies
    - Power and cooling studies
    - And many private studies

4. Worldwide HPC And Supercomputer Market Trends

The worldwide technical server market recovered from the 2008 recession very quickly with an impressive 10% growth in 2010 followed by 8.4% growth overall in 2011. IDC is projecting approximately 7.3% yearly growth overall for the next five years.

HPC major trends include:

- All tech severs are around $10 billion a year in sales today (as shown in the first table below), containing 3.3 million processer packages in 112 thousand systems.
- The boarder HPC market, including storage, software and services is around $20 billion today.
- Supercomputer servers represent around $4.4 billion a year today, in 2.8 thousand systems sold each year.
- The major industry/application uses are shown in the second table below, with government labs, universities, bio-life sciences, defense and manufacturing being larger sub-segments.

The supercomputer portion of the HPC has seen the largest growth due to heavy investments by major nations around the world. Supercomputers grew 25% in 2011, with a number of systems costing over $100 million each. The largest supercomputer in the world today, at RIKEN in Japan cost over $500 million.

Some of the reasons for the strong growth include:

- They are used for increasing national innovation, scientific capability, economic growth & job creation.
- It has become a competitive weapon
    - For companies, universities and governments
    - Global competitiveness is driving R&D and better product designs
- Governments view HPC leadership as critical
    - It use to be 1 large supercomputer – now its multiple ones
- There are very critical HPC issues that need to be solved
    - Global warming, alternative energy, safe NE, financial disaster modeling, healthcare, homeland security, …
    - And 3D movies and large scale games are fun
- At the same time, “live” science and “live” engineering costs have escalated
    - And time-to-solution is months and sometimes years faster with simulations

Some interesting quotes and actions from world leaders:

- In 2009, Russian President Dmitry Medvedev warned that without more investment in supercomputer technology: “Russian products will not be competitive or of interest to potential buyers.”
- In June 2010, Rep. Chung Doo-un of South Korea’s Grand National Party: “If Korea is to survive in this increasingly competitive world, it must not neglect nurturing the

supercomputer industry, which has emerged as a new growth driver in advanced countries."

    - The Korean National Assembly then called for the creation of a national five-year plan for advancing HPC
- In February 2012, the European Commission announced that it has adopted a plan to double spending on HPC to €1.2 billion, with much of that money aimed at the installation of additional petascale supercomputer systems

In summary, there is a worldwide battle for supercomputing leadership taking place around the globe -- it's a tool for economic growth and innovation -- large funding is all that is required these days (well mostly funding). There are some major limitations in the ability to effectively use supercomputers today including: Software lags hardware and the gap has been growing at an alarming rate; and the lack of enough talented people to make full use of the supercomputers.

5. China Information -- And The US Compared To China Supercomputer Trends

China has been increasing their investments and installations of all types of technical servers as show in the charts below. Since 2002 they have increased their yearly HPC purchases by an impressive six-fold and their supercomputer purchases by close to 7 times.

The charts below compare the US to China purchases and clearly shows that the US has a sizable lead in total installations, but China's rate of growth is dramatically higher. The US purchases almost five times the amount of supercomputers that China does each year, but is only growing by around 4% a year, while China is growing supercomputer purchases by 22% a year (since 2002). The rate of increase by China could lead to China becoming a major portion of the world market, resulting in vendors customizing future systems to better match requirements from China buyers.

China today spends about $600 million on technical servers and around $375 million on supercomputer systems. In addition, China is building new institutions and new centers to make better use of these supercomputer assets. They plan to have 17 petascale supercomputer centers in the near future. China already has passed up Germany in the number of Top500 supercomputers and will soon pass up all of Europe combined on the Top500 list (see www.top500.org). Counting total supercomputer purchases, China likely exceed Japan and Germany in the next year or so to become the second largest purchasing country in the world (next to the US).

China's use of supercomputers is very different than in most other countries, in that China views supercomputers as a toll and not as a costly asset. So while other centers work very hard to keep the computers fully utilized, China tends to focus on using the computers to support researchers and train new users. By having this extra "head room" it makes it easier for a researcher with a new idea to get substantial time on the computer. It is a more strategic vision than used by other countries.

China desires to obtain leadership in most or perhaps in all areas. China recognizes the importance of HPC for leadership in many areas and is heavily funding HPC to gain a strong standing in science, innovation and for economic growth.

China understands that "To out-compute is to out-compete" (a quote from the US Council on Competiveness). They still have a lot to learn and a lot to learn and need to build out in their HPC ecosystem -- but they recognize this and are addressing it.

China also wants to be known as an innovative leader and not just a copier (or not as just a low cost, cheap supplier). Today, China has the #2 largest supercomputer, it was #1 last year, but Japan built an even large one. China will likely compete strongly to displace Japan as the leader -- and may increase investments even more than currently planned.

China uses their supercomputers on a very broad set of applications as shown bellow, including oil exploration, bio & life sciences, manufacturing, climate, weather, teaching and animation.

Chinese technologies:

- Chinese CPU efforts -- they are developing 2-3 main home grown processors plus a few others. These are based on existing processor technologies like MIPS, ALPHA, etc.
    - From our surveys of buyers in China, most view the Intel x86 as the processor of choice at this time. There are many rumors about China potentially developing a real strong workable processor of its own, but this isn't my area of expertise.
    - This work is innovative in many ways, but evolutionary in others areas in that each processor technology is based on an existing ISA. They have been developing some of these for many years and for over 6 generations, e.g. the Godson/Loongson, MIPS-based processor that Sugon/Dawning is using in a number of products (see http://en.wikipedia.org/wiki/Loongson).
    - They have also developed innovative ways to use these processors with large systems like the TH-1A that uses SPARC-based processors for system control.
    - These processors are seeing success in a number of supporting application areas, e.g. in modems and internet supporting systems.
    - To develop a competitive processor requires both major strength in R&D as well as major investments and skills in building leading edge fabs.
- China has also developed its own very high speed custom interconnect that is used on the TH-1A supercomputer. But it is costly and not broadly used.
    - This is very innovative when combined with the other innovations within the TH-1A design. Only 3 countries have built a large custom peta-scale class supercomputer (US, Japan and China).
    - The interconnect design appears to be similar to other advanced custom interconnects, but its implementation is unique. It is designed to support a very large supercomputer, with higher costs than can be supported in mainstream computers. This is similar to interconnects created and used by US companies like Cray and IBM.
    - It was developed by NUDT (the National University of Defense Technology http://english.nudt.edu.cn/) and was custom designed for the TH-1A computer.

NUDT has built a number of special and innovative supercomputers for many decades in China.

- China also has created an interesting graduate class exercise in developing programs for breaking/checking passwords. The last slide below shows the result of this classroom exercise -- the student's winning program can check 50,000 passwords a second on each node of the computer, 250,000 per second using the GPUs on a node and when run on the whole TH-1A computer 1.8 billion passwords can be checked per second.
    - China recognizes that large scale supercomputers are required for the design, development and pre-testing of advance aviation, ships and military equipment. They proudly display examples of applying supercomputers for high speed fighters, aircraft carriers, satellites, etc.

In summary, China has many weaknesses in HPC -- but they recognize them and are addressing them -- it will take years, but they will likely do it faster than any country has done before.

- China has put into place many undergraduate and graduate programs to teach the use of HPC and how to apply HPC alongside with basic scientific disciplines. China also has a program to bring back to China top researchers and scientists to help train and develop China's eco-system (the goal is to bring back 100 a year).
- China is placing many of their HPC systems into a "Cloud" for smaller organizations and companies to gain access and to learn how to apply HPC in their company.

6. Recommendations For Our Country

Leadership requires major actions, investments and continued actions & innovation over time.

- Smaller 10% - 25% increases do very little.
- Spreading increases across broad groups of existing organizations also do very little to help with leadership. There needs to be a smaller number of targeted areas for leadership.

Today the US is the clear leader in supercomputing, but the level of our leadership has declined and it will require strong investments and leadership to MAINTAIN our current position:

- An increase of $2 billion a year in purchases of supercomputers would be a good start, plus around $2 billion for the infrastructure required to go with these new systems. Then growing it by 10% a year (note -- this must be new dollars, not just shifting of existing funds).
- An increase on the order of $1 billion a year in HPC R&D funded by the USG for developing better systems and building blocks and software.
    - To work well, at least 50% should go to software that will help application jobs performed better, which in most cases means making able to use more processors or scale better.
    - The software R&D must be separate from the hardware R&D, otherwise the hardware will soak up all the funds (as has been the case in the US for decades).
- A good example would be for the US to take the DOE exascale proposal (whatever it finally turns out to be) and funding it at 2x to 3x the plan -- and then asking DOE how much more they can accomplish and how much faster they can do it with 2x to 3x the funding.

        - Again this needs to be new dedicated funds, not just reshuffling of existing budgets.
    - We also need to address the skill sets, training and lack of scientists, engineers and technical experts in our country. We need multiple "Apollo like" missions that are exciting enough to get students interested AND to get experts from around the world to move to the US. We can never graduate enough within the US, so we must also get technical people from around the world to relocate to the US.
        - For example, how many graduating physicists and astrophysicists would move to CERN if given the chance?

7. Conclusions and Overall Assessment

The bottom line is that China has gone from a non-entity in HPC and supercomputers to having one of the largest in the world in only five years. And they are on a trajectory that is dramatically stronger than the US:

- Five years ago they only had a few supercomputers that would make it onto the list of top 500 computers in the world, today they have more than Germany or France, and very soon they will have more than ALL of Europe combined.
- Their largest supercomputer is larger than any known supercomputer in the US (this excludes classified computers).
- They are investing in 17 different petascale centers (petascale = very large supercomputers) around China, many of which are new and are being built from the ground up.

While it is true that they haven't yet fully developed a broader ecosystem to take full advantage of these assets, they are filling out their ecosystem faster than any country has ever done in history. They fully recognize these short comings and are investing heavily in them.

In addition, their rate of graduating scientists, engineers and analysts that can apply supercomputers and HPC to help advance their national science standing and improve their economic competitiveness greatly outstrips what the US or Europe is able to accomplish. While we don't have exact figures on these numbers it's not in the 10 times stronger range -- it is much higher.

In summary, the Chinese government, at the national and local levels understands the value of HPC and supercomputers in increasing innovation, advancing science and growth their economy. They are investing heavily in both very large systems and in growing the eco-system required to take advantage of these assets.

8. Charts And Tables:

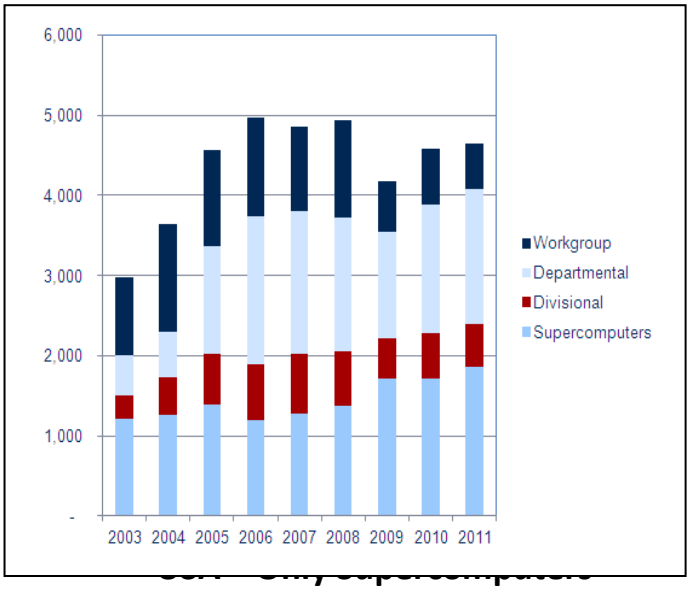
An Overview of The Worldwide Technical Server And The Supercomputer Market

Revenues	2010	2011
Supercomputers	3,476	4,361
Divisional	1,269	1,246
Departmental	3,279	3,481
Workgroup	1,475	1,213
Total	9,498	10,300
Systems Sold	**2010**	**2011**
Supercomputers	2,560	2,811
Divisional	3,914	3,749
Departmental	19,868	21,199
Workgroup	93,502	84,832
Total	119,844	112,591

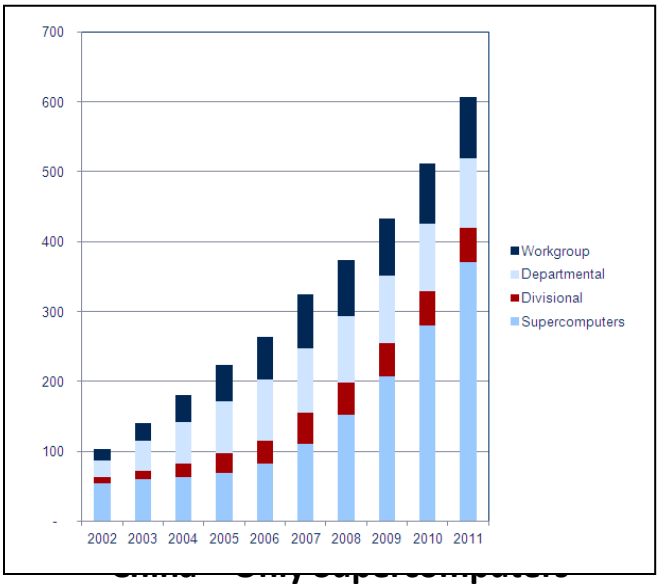
WW HPC Systems Revenue by Applications ($M)	
	2011
Bio-Sciences	$1,252
CAE/Manufacturing	$1,095
Chemical Eng	$193
DCC & Distribution	$569
Economics/ Financial	$279
EDA / IT / ISV	$663
Geosciences	$654
Mechanical Design	$63
Defense	$1,005
Government Lab	$2,078
University/ Academic	$1,901
Weather	$454
Other	$95
Total Revenue	**$10,300**
Source IDC, April, 2012	

How the US Compares to China in Technical Servers (Of All Sizes) and Supercomputers

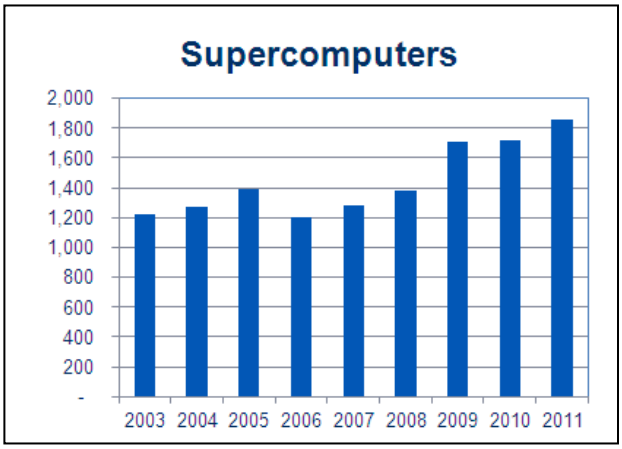
USA—All HPC Servers



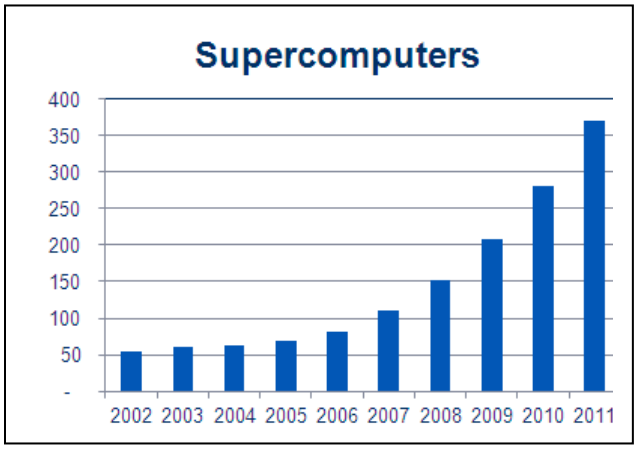
China—All HPC Servers



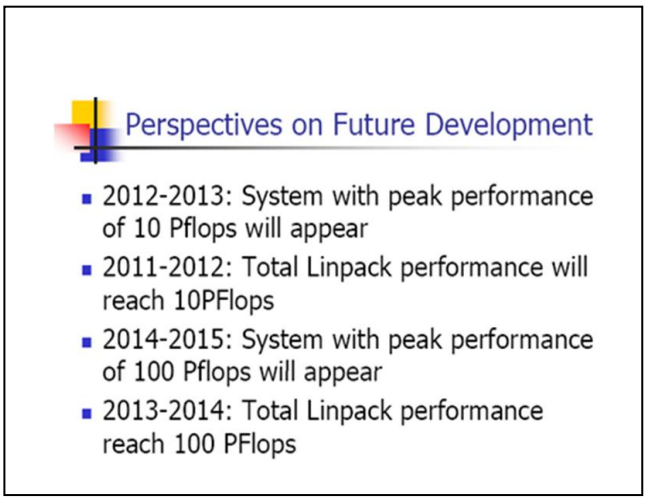
USA—Only Supercomputers

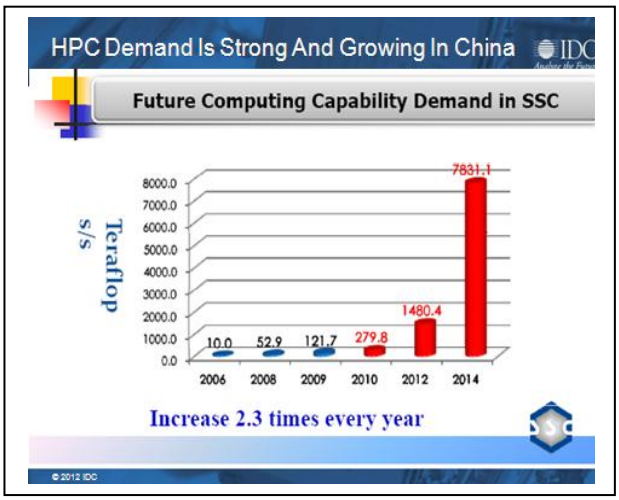


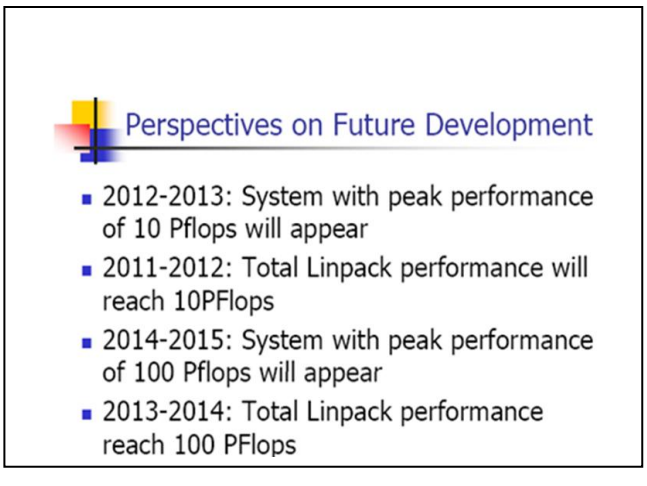
China—Only Supercomputers

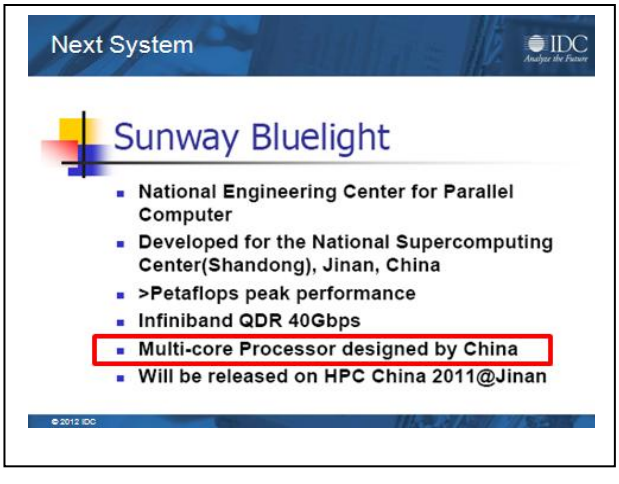


Examples Of How Quickly China Is Increasing Its Budgets And Supercomputer Power

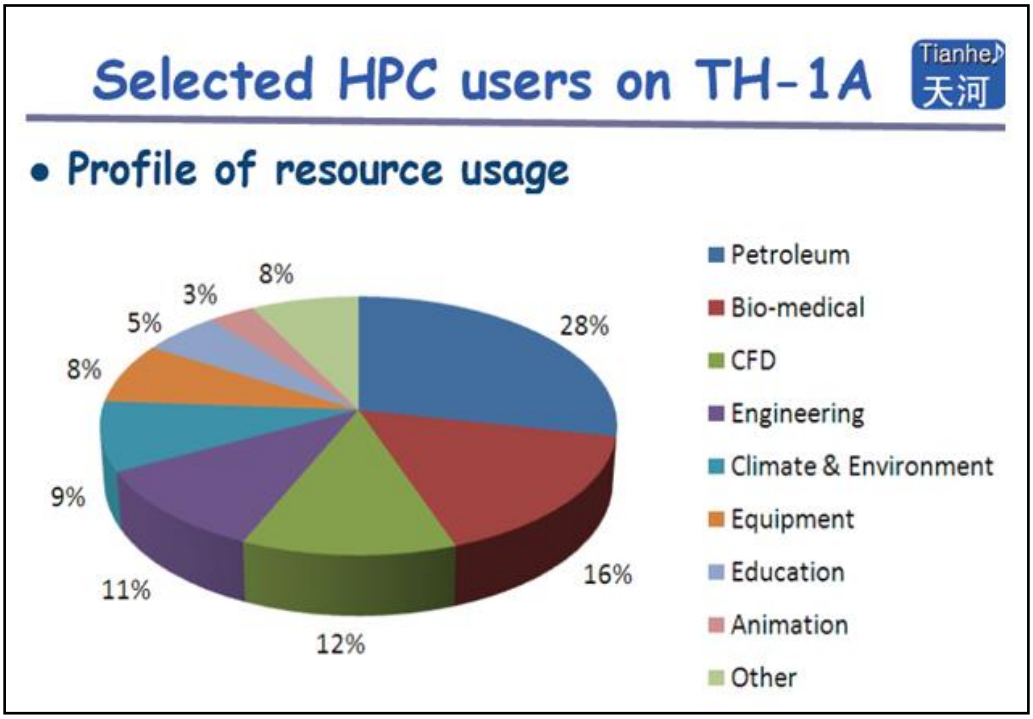


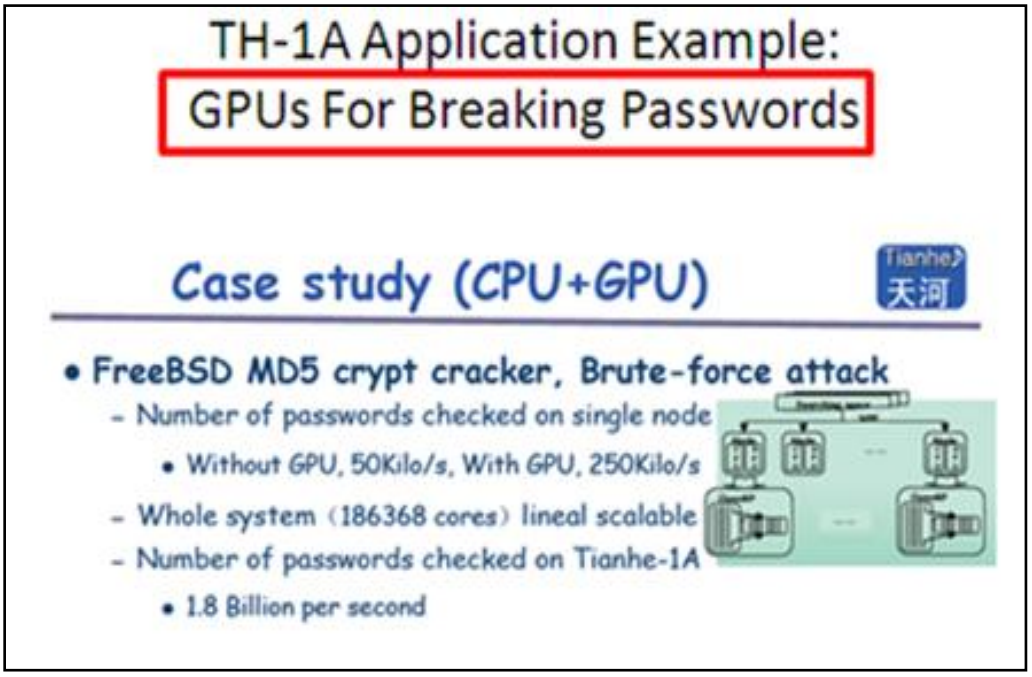






Examples Of How China Is Using Its Supercomputer Power





HEARING CO-CHAIR GOODWIN: That's all right.

Dr. Simon.

STATEMENT OF DR. HORST SIMON
DEPUTY LABORATORY DIRECTOR
LAWRENCE BERKELEY NATIONAL LABORATORY

DR. H. SIMON: Good afternoon.

Chairman Shea, distinguished members of the committee, it's a very great pleasure to be here and report to you, and I will continue, like my colleague Earl, to talk about supercomputing.

Let me first say why I think supercomputing is actually very important and critical to this Commission and to the nation in general. The reason is that supercomputing actually reaches into our society in three different ways.

One is you need these very high, powerful, top-of-line machines to be competitive in science. So if you look at the distribution of supercomputers, there is a direct correlation of a country's scientific standing in the world and the amount of computing resources the scientists have.

This is something that has changed in the last decade that you will find probably no major university in the U.S. that will say we don't need computers, we'll just work with pens and paper. Computing has become an integral part of scientific research, and many scientific disciplines require the most powerful computers.

The second reason for the importance--and so this relates back to the discussion we just had before lunch--it is a scientific instrument. The second reason for the use of computers is, of course, in national security, and we talked about the supercomputers in the U.S.

So currently in the United States, it is very important to note that about half of the supercomputers that are installed in the U.S. have one or the other application that is related to national security. So this is in the U.S., mostly the Department of Defense and Department of Energy, for nuclear weapons research as well as the Department of Defense for cryptanalysis and related applications.

So it is clear that this ties into the discussion that follows later for the national security and supercomputing go also hand-in-hand.

The third one is, and this is also what Earl Joseph already alluded to, is supercomputers are very important for economic development. Large-scale, engineering-based companies, such as aerospace, oil and gas, rely on supercomputers for building for next-generation technology, for doing oil exploration, and increasingly small and medium sized enterprises are using supercomputers for modeling and simulation.

So investment in supercomputing, developing a supercomputing environment is critical for a country like China, and consequently China has taken a number of steps to make significant progress as was already explained.

I would like to distinguish here something that is very important, and because of the wide range of applicability of supercomputing technology, we have to think about, as the National Academies puts it in a recent report, the supercomputing ecosystem. So it is not just the individual machine, but it's a number of factors and elements that build around the supercomputers that are really important.

These factors are the technology-base, the ability to build large systems,

the software for these systems, the applications and the human capital.

Let me make a few remarks about the state of affairs in China with respect to these different factors. As was pointed out already, China has just as a general IT strategy developed a number of indigenous technologies in terms of process, more recently, also, in terms of interconnect, that are important building blocks for supercomputers.

So they are not only applicable to supercomputers but to IT in general. What's relevant for supercomputing is that none of these developments have been at this point breakthrough or forward-looking, but, as was pointed out, are, in a sense, adaptations of publicly-available designs that are used by the U.S. Basically most of the microprocessor designs are modifications of American designs.

So like in many other areas of science and technology, China is, as was said this morning, following, but it's not leading, the innovation.

The second part I wanted to talk about is the large-scale systems. So we heard already about the Chinese aggressive deployment of a large number of supercomputers nationwide. Just to put this again in perspective, ten years ago, in 2002, the Chinese did not have a single system on the Top 500 List. Now, they have 65. That means 65 of the most powerful computers in the world are in China, and as it was pointed out already, the number two and the number four system on the list are in China.

So the Chinese have done two things: they have moved to the top of the pyramid, but they did not neglect the bases and also installed a large number of systems at a smaller scale so that they can cover a whole range of applications, a whole range of user communities.

It's also important to note that these systems are about half built or integrated by Chinese companies. The other half by U.S. companies. So, as was pointed out this morning, the Chinese market is not as close as the Japanese market in supercomputing was in the '90s, but companies such as HP and IBM are fairly successful in placing their systems.

However, what is more important is, as I said before, half of the systems are indigenous Chinese development, some with innovative technology, and they are developed by companies such as Dawning, but also by university programs, such as the National Defense and Technology University.

One interesting aspect of those systems is that they are also deployed very widely, as was already pointed out, and so regional governments and cities are actually encouraged to contribute to the funding for these supercomputers and have deployed these systems in regions that have no real supercomputing infrastructure with the intent that the systems would help in the regional economic development.

I had recently visited a system in Tianjin. On the positive side, it was a wonderful great system. It's the number two system on the list. But it has not had the high utilization that we usually see in American supercomputers of a similar stature. I think that means there is still development work to be done to actually make use of those systems.

Let me comment briefly on system software. Just like in base technology, most of the system software that the Chinese develop is a derivative of open source technology that is available. They have developed their own Linux systems like, for example, the Red Flag Linux system. Again, this is a general trend that China wants to

take many of these technologies indigenous in order to have control over it in terms of national security concerns by the Chinese but also by having a competitive advantage of having lower-priced domestic products.

Let me come to what I think is probably the most important part, the applications, and let me quote something which is maybe not appropriate for this group here. That is Pink Floyd.

[Laughter.]

DR. H. SIMON: My colleague who traveled with me recently to China said when you look at the Chinese supercomputers, that's just like in this movie Pink Floyd in Pompei. You can buy a man a Les Paul guitar, but you don't make him an Eric Clapton.

And so I think this is a really good analogy. The Chinese have bought a lot of Les Paul guitars, but they have not yet succeeded in finding the Eric Claptons.

So what I mean by that is by applications is this is the real big challenge for supercomputers, as we know, to actually make them effective tools for scientific investigations, as tools, as mentioned our nuclear stockpile, and also doing innovative things such as looking at biological applications.

Supercomputer applications take about maybe a decade to develop, and if you look back, in the mid-'90s, for example, our colleagues in the NSA started building the large nuclear stockpile stewardship codes. These codes require a large number of people, a large software infrastructure, and a continued level of support to make them effective tools.

The same model is also used elsewhere by researchers funded by the National Science Foundation, by the DOE Office of Science. So when I look at China, China clearly is not there yet. I was on the evaluation team of scientific applications that compete for the so-called Gordon Bell Prize for supercomputing last year, and this was the first time that I saw Chinese entries in the competition. They were very good, but they were not yet the top, and so my judgment was that just--and this is my personal judgment--looking at these entries, if they had been submitted ten years ago to the same competition, they would have been number one.

So my guess is that China is in terms of application development probably ten to 15 years behind.

I'm running overtime already so I will conclude this, and just make one more comment on human capital, and I think in terms of human capital, I alluded to it, it is, the question is how can the uses of supercomputers, how can they be trained?

This is a big challenge, I think, also for another reason, which is a cultural challenge. I think China, as was also said this morning, is still very hierarchical in terms of its academic infrastructure, with respect to the top, and stovepiped. That is there's very little understanding of collaboration between disciplines. Both things are elements that are absolutely critical that have to be developed when we go in and engage in supercomputing applications.

So let me conclude and summarize this, and sorry for being that much overtime, I think that China has made tremendous progress in the last decade to become competitive in supercomputing, has competitive offerings, but in some aspects still has quite a bit to go. However, that doesn't mean we should, in a sense, sit back and say fine, a superpower, an economic superpower, also wants to be a supercomputing power.

PREPARED STATEMENT OF DR. HORST SIMON
PROGRAM VICE PRESIDENT, IDC

Testimony before the U.S. – China Economic and Security Review Commission

Date:
Thursday, May 10, 2012

Name of the panelist:
Horst D. Simon

Panelist's Title and Organization:
Deputy Laboratory Director, Lawrence Berkeley National Laboratory, Berkeley, CA 94720

Title of Hearing:
Assessing China's Efforts to Become an Innovation Society—A Progress Report.
Panel IV: Information and Communications Technology Innovation.

Outline:
1. My Background
2. General comments about the role of supercomputing and high performance computing
3. Assessment of supercomputing developments in China
4. Exascale computing and future developments
5. Summary and Conclusions

Many thanks to the Commission for the opportunity to testify at this important hearing. I am honored to have been asked and am happy to share my perspectives and insights, and hope that they are helpful to your deliberations.

1. My Background

I am the Deputy Laboratory Director of Lawrence Berkeley National Laboratory (Berkeley Lab or LBNL), a large (about 3400 FTE staff and $750M annual budget) Department of Energy multiprogram laboratory, managed by the University of California, located in Berkeley, California. LBNL's mission is to conduct research in

the physical sciences, biosciences, and computing sciences in order to address some of the most challenging problems that the nation and the world face in the areas of energy and environment.

Previously, from 1996 to 2007, I was Director of the National Energy Research Scientific Computing Center (NERSC) and from 2003 to 2010 Associate Laboratory Director for Computing Sciences at LBNL. NERSC is one the largest supercomputer centers in world, supporting a broad base of scientific applications of relevance to the DOE mission. I have been an active researcher in supercomputing algorithms, performance evaluation, and applications throughout my career that has also included positions at Boeing, NASA Ames, and SGI. I am a member of the TOP500 team that publishes the bi-annual TOP500 list of the most powerful supercomputers in the world. This list has become a valuable tool to asses technology developments, and geographical and business trends, in high performance computing and supercomputing.

The current testimony is based on my 30 years of experience in the field having observed supercomputing almost since its beginning in the 1970s. I would like to thank my colleagues Jack Dongarra, Hans Meuer, and Erich Strohmaier from the TOP500 list, David Kahaner from the Asian Technology Information Program (ATIP), and colleagues from ICCS (International Center for Computational Science, Beijing, Berkeley, Heidelberg) for discussions and contributions. My testimony also includes some anecdotal information from a recent trip by Hemant Shukla (LBNL) and myself to Beijing and Tianjin, including visits to National Astronomy Observatory of China (Chinese Academy of Science), Electrical Engineering Department at Peking University and Kavli Institute for Astronomy & Astrophysics, National Supercomputing Center, Tianjin (computer named Tianhe 1A – ranked no. 2 in the world), and Institute of Process Engineering (computer named Mole 8.5).

2. General comments about the role of supercomputing and high performance computing

The term High Performance Computing (HPC) generally refers to all computing infrastructure and activities that contribute to the computational solution of difficult scientific and engineering problems. HPC encompasses a very wide range of technologies and activities ranging from desktops to supercomputers.

Supercomputers are computing systems that provide close to the best possible computational performance at any given time. Supercomputers are often uniquely

built systems that cost in the tens of millions to low hundreds of millions of dollars. By definition, at any given point in time, there are only about 50 to a 100 supercomputer worldwide.

Supercomputing refers to the various activities related to the design, manufacturing, and use of supercomputers, and is thus a subset of HPC. While supercomputing is in some sense a niche in the general computing world, it has tremendous impact because of its strategic importance for a country in three respects:

- Scientific competitiveness: as computation has become recognized as a mode of science of equal importance to theory and experiment, supercomputers have become an essential tool for basic science from nano science to cosmology
- National security: supercomputers essential tools for national security applications from the modeling of the nuclear stockpile to cryptanalysis
- Economic competitiveness: the use of supercomputer modeling in industrial applications from aerospace to geosciences, as well as the use of supercomputers for data intensive applications creates a competitive advantage.

In order to understand the relative state of supercomputing in a country it is very important to consider the ecosystem of supercomputing. The term "ecosystem" was used by the National Academies Study "Getting up to Speed, The Future of Supercomputin." Ecosystem refers to the fact that technologies, computer systems, software, applications, and human capital have to be developed simultaneously in order to make progress in supercomputing. They form an interlinked and mutual reinforcing system. I believe that the notion of ecosystem is essential to understand progress in the field, in particular as it relates to a nation such as China that is developing supercomputing capabilities.

3. Assessment of supercomputing developments in China

I will briefly address the components of the supercomputing ecosystem in China.

a) IT technology

The Chinese government has a consistent and long applied set of policies to encourage the development of local (domestic) IT companies and to build out the country's IT ecosystem, from device design to product development, system

integration, standardization, and through to sales and service channels (modern IC fabrication facilities are a missing component). These policies include investments in basic and applied R&D, tax incentives, favorable procurements, transfer of experts from research organizations including universities and national institutes into start-up companies rolled out from research labs, etc. Examples of companies that have succeeded via this formula include Lenovo, Dawning, and Inspur. The "wall" between company and university is much less solid in China compared to the US.

China states that it is in their national interest to develop domestic IT IP for economic benefit, assurance of content, price, and national security. China has a very large and growing domestic market; products that can succeed locally might also be suitable for export. Chinese IT leaders believe that domestic hardware is only a few years behind world levels, but acknowledge that thus far, designs are largely following and adapting Western ideas. They also recognize that, regarding software applications, China is further behind and is only likely to catch up in limited sectors where local content can add significant value, such as GIS. Regardless, domestic developments not only benefit local organizations directly because of low price but also put price pressure on multinational products, and there is evidence that is a successful strategy.

b) HPC Systems

There are three, essentially independent, HPC developments; two utilizing modifications of Western processors and incorporating GPUs (accelerators). There is one indigenous processor effort. In all these systems the domestic engineering content is solid and can be directly traced to either a university or a research institute. Chinese government officials believe that development of both processors and software is necessary in order to build a domestic IT ecosystem. The national government is encouraging experimentation with different approaches to HPC architecture; at the same time there is some evidence that the technical community would prefer more standardization. The national government has also been encouraging and supporting the diffusion of HPC systems across the country. City (Beijing, Shanghai, etc) and provincial governments have been supplementing national support in order to acquire large systems. To some extent this is driven as a "build it and they will come" philosophy as well as competition between communities for HPC bragging rights. Nevertheless, systems sited locally are definitely enhancing local capabilities, especially if they include research and outreach components.

With today's processor technology, given adequate resources, it is relatively easy to build extremely large systems – hence China's recent entries into the well known Top 500 HPC list. In the Chinese equivalent (Top 100), domestic and multinational (primarily US) systems are equally represented, largely as a result of government support to domestic organizations. There is no indication this trend is abating.

c) Systems Software

China has done a good job leveraging open source software. This is particularly true regarding system software; Linux is the operating system (OS) of choice in nearly all large systems. The Chinese company, Red Flag is significant in this market at the low end and NFS at the server side (both spun out of the Chinese Academy of Science, Institute of Software). Another Chinese Linux derivative is Kylin produced by the National University of Defense Technology). Homegrown OS products are given priority in government procurements. In this context, the most likely growth is on the server side -- local server OS products have been gradually accepted by users and deployed in government and critical areas such as the state power grid due to their low price, controllable security, and lack of visibility to end users. There is also considerable government support for the development and deployment of Linux-based mobile OS because of that sector's potential market size.

d) Applications

Making effective use of any large system is challenging. Most supercomputer users are traditionally supported by government (including national defense, aerospace, weather, etc), basic science (physics, astronomy, geosciences, biology, etc), combined with automotive, mechanical, game/video, energy (oil/gas) and "knowledge" industries (e.g., search, social media).

Large-scale applications software is much weaker than hardware, although there is a considerable amount of local content. This is an important issue to the Chinese as multinational products are very expensive. In addition, key modules may be removed before importing. A typical domestic application software product can be viewed as a scale up of a small university or institute research effort. Examples are JASMIN, PHG, and GeoEast. The "scale" of applications, especially government research topics, is increasing but not yet at US levels. Further, while Chinese application software may be "good enough," compared to large US HPC applications

the Chinese efforts lag considerably, not only in technical content, but in the relative lack of sophisticated use of modern software engineering, languages, and tools for their maintenance and expansion. Recently, government research investments have shifted toward software, encouraging the development of packages capable of running effectively on very large systems. This is potentially a significant development.

In spite of having access to large systems, so far there has been no winner or finalist in the annual ACM Gordon Bell Prize from China. I served on the selection committee in 2011, and there were several notable and very accomplished submissions. However, they did not yet quite reach the international competitive level in 2011, but in my judgment could have been a winner 10 years ago.

e) Human capital

I recently attended a workshop organized by ICCS in Beijing. It was evident that a lack of command of the English language remains a significant barrier for most students in becoming current and gaining expertise. Lack of learning materials further exacerbates the situation. However, the vigorous enthusiasm to learn is evident and therefore for many students who have crossed over the language barrier performance is commendable. The US remains the educational beacon for many aspiring students. While I don't want to generalize from a personal experience, it is clear that developing a community of experts in supercomputing requires times and is a task that will take 15 – 20 years.

A second issue that I can only speculate on is the fact that academic organizations China remain still hierarchical and stove piped. In a field such as supercomputing with rapid technology change and the need for large team work and multidisciplinary collaboration, an "academic" structure seems to a barrier to progress.

The state funding mechanism of Chinese supercomputers provides for the overall cost of building and hosting the system, while the facilities have to bear the operational costs. In order to raise annual operating costs, the facilities charge money for compute cycles – for example, Tianhe 1A charges one Yuan per core hour. This leads to an interesting bias towards industrial applications because the academic counterparts cannot afford the costs. Several researchers mentioned in conversations to me that they rather stay on their smaller local systems. This could be potentially a big barrier to the further development of supercomputing expertise.

4. Exascale computing and future developments

Since about 2007 US researches have set their sights on the next big goal in supercomputing: reaching the Exascale level. After several years of careful planning, workshop, and developing strategy documents, the U.S. efforts now face current federal budget realities that may lead to a more limited exascale program. In this context, Chinese developments are receiving increased attention, and each new technology announcement leads to exaggerated statements about "the Chinese are winning the Exaflops race".

Research toward the next level HPC target (Exascale) is underway, but cautiously, and Chinese researchers are carefully monitoring developments abroad, including participation, whenever possible, in open international fora. Thus far, there is no evidence that China will provide leadership in this direction.

Yes, there is national pride that Tianhe 1A was at least for one instance of the TOP500 list the #1 system in the world. But I would put this in the same category, as national pride over running a very successful Olympics. As a matter of fact, as one Chinese colleague remarked during my recent trip along these lines "... yes, China is investing in many areas of research and technology but nothing happens until the U.S. leads."

5. Summary and Conclusions

In summary, China's supercomputing activities should be viewed objectively. Recent Chinese successes neither indicate that US leadership is about to be supplanted, nor should they be minimized. The reality is that Chinese developments are strong and are improving rapidly, but there are many weak spots. China has people, resources, and commitment to succeed in supercomputing, and is deploying these strategically. An emerging economic superpower will also want to be a supercomputing power.

HEARING CO-CHAIR GOODWIN: Thank you, Doctor.
Mr. Harder.

STATEMENT OF TIMOTHY K. HARDER
DIRECTOR, EMC CLOUD INFRASTRUCTURE DIVISION

MR. HARDER: Mr. Chairman, members of the Committee, thank you for the opportunity to contribute to today's hearing.

China is investing in cloud computing on an industrial scale. Its government, state-sponsored industry and academic institutions are operating in a coordinated fashion to construct a national asset platform for accelerating the pace of technical innovation.

The initial infrastructure rollout approved by the Ministry of Commerce in 2011 as part of the 12th Five Year Plan will direct over $300 billion in U.S. equivalent of domestic information technology investments with cloud computing receiving a beneficial share of the funding.

Cloud computing represents to China a vehicle to showcase their vast resources and ambitions. China is a late entrant to the field of cloud computing, but any detrimental position caused by the delay in execution is quickly being offset by their current pacing and the sheer volume of investment.

China who desires to become a net exporter of cloud services will leverage its resources to create jobs in directly related categories and in the extended supply chain.

In some key areas that we'll review briefly, China is outspending the United States federal government by nontrivial orders of magnitude. This misaligned spending will add to the advanced persistent threats against our nation's critical infrastructure, has the potential to further challenge our cyber warfare posture, and seeks to attract the same foreign direct capital pool for innovation that could be deployed here in the United States.

To date, China's indigenous technical innovation attributed to cloud computing software has been surprisingly limited. The first formal Chinese body organized for the pursuet of cloud computing was assembled in January of 2010 under the direction of the Ministry of Industry and Information Technology.

In a model and format well known to other industries, the new formal body, China Cloud Computing and Industry Alliance, has been seeking to establish a roster of experts from around the globe to educate their elite and extensive scientific community on the new methods of cloud computing.

Now, in its second year of operation, the CCTIA has benefited from the contributions of individuals, small but innovative firms, and major technology suppliers alike. The size and the breadth of the effort can be difficult to quantify for the committee, but as a baseline, the Chinese Institute of Electronics, an appendage to the Ministry, represents over 100,000 members of China's engineering community in 30 different provinces.

They're actively participating through direct member involvement and in a solicitation of industry expert panels.

Where China is lagging in its domestic production of cloud computing software, it is excelling in its commitment for sourcing commodity infrastructure

components and property and plant build-out to house its acquired computing assets.

While multibillion dollar cloud computing efforts are underway in Beijing, Shanghai, Shenzhen, Hangzhou and Wuxi, with the benefits of technical contribution from the university systems in each of these cities, the largest effort underway by a wide margin is in the municipality of Chongqing.

In Chongqing, a city-sized cloud computing complex is being constructed. The Liangjiang International Cloud Computing Center broke ground in January of 2011. In terms of scale, a single data center in the complex is planned to be physically larger than the Pentagon.

At a point in time where our own nation is closing more than 1,000 data centers through the Federal Data Center consolidation effort, China is building millions of square feet of new data centers to house their cloud computing platforms.

Chongqing is an interesting site selection for such a large cloud computing infrastructure in the country of China. A direct controlled municipality with approximately 30 million residents, Chongqing, now under the leadership of Chinese Vice Premier, serves as an outpost for many global technology suppliers, specifically, technology suppliers that excel in manufacturing commodity line components that are to be the foundation for cloud computing environments.

In Chongqing, China has an integrated supply base that can readily produce the hundreds of thousands of units that will be needed to fully populate these new cloud computing environments.

Dual-use capabilities are inherently constructed in the cloud computing stake today, which permit an operator of an otherwise benign appearing system to deploy it for civilian pursuits in the arts, finance, education, or health care one moment, and in the very same system for national strategic pursuits the next.

The software technology exists today and is being deployed in China at a rate without precedent. The aggregation of resource pools being constructed in Chongqing alone for national strategic purposes could easily double the scale of the advanced persistent threat facing the United States critical infrastructure.

Construction of these major centers is being directed and financed through a combination of national level policy and at a provincial level. While cloud computing in China offers the promise of reducing costs for domestic firms of all sizes, it offers for the innovation community a combination of unique opportunity and a unique threat profile.

Cloud computing offers an individual technology consumer the ability to harness a vast resource pool with very limited expense. The model is especially interesting for small firms that do not yet have access to expansion stage capital or cannot afford to procure their own systems.

Cloud computing lowers the economic threshold for good ideas to reach the global market. This, however, leaves the innovative consumer in China with the tradeoffs of risk and control: risk in that cloud computing assets being leveraged are effectively state controlled and can be shut off at any time; control in that these centralized points of management at the provincial level offer an easier footprint to censor.

China's near and mid-term prospects are favorable at a sovereign national level, at a domestic consumption level, and as a consumer for technology providers. The 12th Five Year Plan directs spending for information technology assets that will

benefit global technology providers while China continues to assemble its domestic industrial base for supplying cloud computing software.

From the perspective of domestic consumption, it offers organizations a unique opportunity to reduce operating costs and balance sheet expenses for warehousing computing infrastructure, and at a sovereign national level, China is constructing a massive cloud computing infrastructure that can be used for civilian benefit or other strategic pursuits.

Thank you.

PREPARED STATEMENT OF TIMOTHY K. HARDER
DIRECTOR, EMC CLOUD INFRASTRUCTURE DIVISION

May 10, 2012

Timothy K Harder

Testimony before the US-China Economic and Security Review Commission

Assessing China's Efforts to Become an "Innovation Society": A Progress Report

Mr. Chairman, members of the Committee, thank you for the opportunity to contribute to today's hearing. China is investing in Cloud Computing on an industrial scale. Its Government, State Sponsored Industry and Academic Institutions are operating in a coordinated fashion to construct a national asset platform for accelerating the pace of technical innovation. The initial infrastructure roll out approved by the Ministry of Commerce in 2011, as part of the 12th Five-Year Plan will direct over $300B of domestic information technology investments with Cloud Computing receiving a beneficial share of funding. Cloud Computing represents to China a vehicle to showcase their vast resources and ambitions. China is a late entrant to the field of Cloud Computing but any detrimental position caused by their delay in execution is quickly being offset by their current pacing and sheer volume of investment. China who desires to become a net-exporter of Cloud services, will leverage its resources to create jobs in directly related categories and in the extended supply chain. In some key areas that we will review, China is outspending the United States Federal Government by nontrivial orders of magnitude. This misaligned spending will add to the advanced persistent threats against our critical infrastructure, has the potential to further challenge our cyber warfare posture and seeks to attract the same foreign direct capital pool for innovation that could be deployed here in the United States.

During the last 15 years I have been on the cutting edge of technology creation, investment and management for the Enterprise and Government markets. I have helped guide four start-up organizations from incubation to over $2B in aggregate revenue, managed technical and commercial relationships in more than 35 different countries and have spent a significant amount of time in China. In 2007 my team developed one of the first commercially viable Cloud Computing platforms designed to protect information assets. During the most recent five years, the technology we created has become the foundation for some of the largest Cloud systems in the world. I have been recognized as an industry leader on the topic by the Department of Defense, contributed to the House Oversight and Government Reform Hearings on Cloud Computing and I write the popular educational blog @GovCloudTalk. My remarks, written testimony and any related discussions for the US-China Economic and Security Review Committee may coincide with the views of my employer but do not necessarily represent them. The views expressed herein are entirely my own.

Cloud Computing is both a collection of discreet technologies and deployment business models. The National Institute of Standards started its valuable work to craft a formal definition in 2009 and published its final definition in October of last year. According to the official NIST definition, cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. The NIST definition lists five essential characteristics of cloud computing: on-demand self service, broad network access, resource pooling, rapid elasticity or expansion and measured service. It also further lists three service models (software, platform, and infrastructure) and four deployment models (private, community, public and hybrid) that together identify the delivery of computing services. For our purposes here I might

suggest to the committee to think about Cloud Computing as an aggregation of technical resources, across extended geography, that offers an easy way for operators to mange a very vast pool of computing power. An important point not captured in the formal NIST definition of Cloud Computing but one that is widely accepted in the commercial community is in building this new type of computing resource pool using commodity off the shelf components. COTS equipment is cheaper to build, cheaper to own and cheaper to operate than equipment built to unique or exacting specifications. Most large purveyors and institutional consumers of Cloud Computing readily deploy commodity components for the costing benefits and availability of market supply. The unique attributes set forth in the NIST definition are achieved principally through software. This nuance is important to understand as it speaks to where current innovation is actually occurring and where next generation breakthroughs are apt to originate. That is: In Cloud Computing Software. Not the hardware assets that power them.

To date, China's indigenous technical innovation attributed to Cloud Computing software, has been surprisingly limited. The first formal Chinese body organized for the pursuit of Cloud Computing was assembled in January of 2010 under the direction of the Ministry of Industry and Information Technology. In a model and format well known to other industries, the new formal body, China Cloud Computing and Industry Alliance (CCCTIA), has been seeking to establish a roster of experts from around the globe to educate their elite and extensive scientific community on the new methods of Cloud Computing. Now in its second year of operation, the CCCTIA has benefited from the contributions of individuals, small but innovative firms and major technology suppliers alike. Commercial suppliers are readily participating in the exchanges for the benefit of establishing thought leadership in the domestic China information technology market and for the opportunity to compete for integration and supply contracts. Practically speaking, participants are aware that their ideas, methods and unique intellectual property may be co-opted but do not wish to be excluded from commercial opportunities for lack of engagement. The size and breadth of the effort can be difficult to quantify for the Committee, but as a baseline, the Chinese Institute of Electronics, an appendage body to the Ministry of Industry and Information Technology that represents over 100,000 members of Chinas engineering community in 30 different provinces is actively participating through direct member involvement and in the solicitation of industry expert panels. China is currently lagging behind in its domestic production of Cloud Computing software but this is not hindering its capabilities as best in breed software titles are readily available for purchase through global supply channels. In many instances, open source derivatives of commercially supplied Cloud Computing software packages can be downloaded from the internet and are accessible to anyone with an introductory proficiency to the technologies.

Where China is lagging in its domestic production of cloud computing software it is excelling in its commitment for sourcing commodity infrastructure components and property and plant build out to house its acquired Cloud Computing assets. While multi-billion dollar Cloud Computing efforts are underway in Beijing, Shanghai, Shenzhen, Hangzhou and Wuxi with the benefits of direct technical contribution from the University Systems in each of these cities, the largest effort underway by a wide margin is in the municipality of Chongqing. In Chongqing, a city sized Cloud Computing complex is being constructed. The Liangjiang International Cloud Computing Center broke ground in January of 2011, in terms of scale, a single data center in the complex is planned to be physically larger than the Pentagon. At a point in time where our own nation is closing more than 1000 data centers through the Federal Data Center Consolidation effort, China is building millions of square feet of new data center space to house its Cloud Computing platforms. Chongqing is an interesting site selection for such a large Cloud Computing infrastructure in the country of China. A direct controlled municipality with approximately 30 million residents Chongqing, now under the leadership of Chinese Vice Premier Zhang Dejiang, serves as an outpost for many global technology suppliers. Specifically technology suppliers that excel in manufacturing commodity line computing resources that are to be the foundation of Cloud Computing

environments. In Chongqing, China has an integrated supply base that can readily produce the hundreds of thousands of units that will be needed to fully populate the new Cloud Computing environments. But the location is not without its challenges. Chongqing is plagued with excruciatingly high temperatures, high humidity and an electricity system that, by western standards, experiences significant levels of downtime. I highlight for you these three characteristics, which under normal circumstances, would be completely avoided when attempting to site a new data center for facilities that house Cloud Computing infrastructures as they are dependent upon a stable power grid and carefully orchestrated cooling processes to maintain the computing equipment in a beneficial operating condition. China is innovating in the areas of cooling and power distribution but there must be another strategic imperative for selecting Chongqing to house such a massive new environment. With Chongqing's close proximity to the Chengdu Military Region and other assets which contribute to the Peoples Liberation Army Information Operations it takes only a marginal inference to suggest the these new environments can contribute to both civilian and military pursuits. Recall that one of the benefits of Cloud Computing, embedded in its official definition, is the ability scale and dynamically retask an environment in rapid fashion. Dual use capabilities are inherently constructed in the cloud computing software stack today which permit an operator of an otherwise benign appearing system to deploy it for civilian pursuits in the arts, finance, education or healthcare one moment and use the very same system for national strategic pursuits the next. The software technology exists today and is being deployed in China at a rate without precedent. The aggregation of the resource pools being constructed in Chongqing alone for national strategic purposes could easily double the scale of the advanced persistent threat facing the United States' critical infrastructure.

Construction of these major centers is being directed and financed through a combination of national level policy and executed at a provincial level. While Cloud Computing in China offers the promise of reducing technology costs for domestic firms of all sizes it offers for the innovation community a combination of unique opportunity and unique threat profile. Cloud Computing offers an individual technology consumer the ability to harness a vast resource pool with very limited expense. This model is especially interesting for small firms that do not yet have access to expansion stage capital or cannot afford to procure their own systems. Cloud Computing lowers the economic threshold for good ideas to reach the global market. This, however, leaves the innovative consumer in China with the tradeoffs of risk and control. Risk in that the computing assets being leveraged are effectively state controlled and can be shut off at any time, control in that these centralized points of management at the provincial level offer an easier footprint to censor.

Chinas near and mid-term prospects are favorable at a sovereign national level, at a domestic consumption level and as a consumer for technology providers. The 12th five-year plan directs spending for informational technology assets that will benefit global technology providers while China continues to assemble its domestic industrial base for supplying Cloud Computing Software. From the perspective of domestic consumption it offers to organizations a unique opportunity to reduce operating costs and balance sheet expenses for warehousing computing infrastructure. At a sovereign national level, China is constructing a massive Cloud Computing infrastructure that can be used for civilian benefit or other strategic pursuits.

China is a late entrant to the field of Cloud Computing but any detrimental position caused by their delay in execution is quickly being offset by their current pacing and sheer volume of investment. China is innovating in the Cloud Computing supply chain, by necessity in power and environmental cooling systems and building its initial capabilities on a combination of globally source software and open source derivatives. China who desires to become a net-exporter of Cloud services is building a computing infrastructure that can be leveraged for both commercial purposes and national strategic pursuits. China is outspending the United States Federal Government by nontrivial orders of magnitude. This misaligned spending will add to the advanced persistent

threats against our critical infrastructure, has the potential to further challenge our cyber warfare posture and seeks to attract the same foreign direct capital pool for innovation that could be deployed here in the United States.

PANEL III: QUESTION & ANSWER

HEARING CO-CHAIR GOODWIN: Thank you. Thank you, gentlemen.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you, gentlemen, for being here. These are some cutting edge issues, and so your help is appreciated.

I have questions both on the cloud and the supercomputer side, but let me start with the cloud side, if I can, and make sure I understand. We had this migration, if you will, of imbedded software on the unit 20 years ago to you put your own software and storage on the unit; then the storage moved offsite. Now, we're moving the software off site, which is the cloud context, so that you can access it from an iPad or anything else, and everything is available to you.

You talked about some cyber threats. As we see China moving more to the cloud, are they becoming an international player, such that if a U.S. entity is looking for the cheapest way to handle their data software needs, et cetera, China might be an effective supplier of that?

And what risks in the supply chain or to the data, to the manipulation of that data, are created? Are they magnified by going to the cloud because you lose control?

MR. HARDER: Commissioner, thank you for your question.

I think it's an important one. China desires to become a net exporter of cloud services in addition to its own domestic-based uses. So that, in fact, is targeting--

COMMISSIONER WESSEL: But let me say, when you say net exporter of cloud services, that means that my using my computer here, my data and the software may be in China; is that right?

MR. HARDER: That's correct. A desire to sell its services to U.S.-based consumers of the technology. Does it increase the potential for the data to be exploited if it's housed in those data centers? The answer is absolutely yes, it increases the risk profile.

There are steps that can be taken, I think, to alleviate many of those concerns and many of those burdens. It's important to point out, however, that the software that China is using today is open source. They haven't innovated many of the software packages that are being used. They're downloading them off the Internet from U.S.-based sources, coming out of the university systems here, and from other commercial, global commercial suppliers, and I think there are methods and means to accurately, more effectively protect that data, but right now there is not a large volume of deal flow, as I would think about it, being offshored to China.

COMMISSIONER WESSEL: If you're looking at cloud resources like Microsoft 365, and we've heard--I don't even remember the numbers of the amount of IPR theft in China and how few licensed versions--is there similarly with our cloud computing software here and platforms the ability of IP theft to throw those on to China's export of cloud services? Meaning do we have an exponentially greater problem than we've had just in taking one copy of Windows and copying it eight million times or whatever?

MR. HARDER: There is an expectation from the vendor and the supply community that when engaging with China today, you anticipate that the software is going to be co-opted. Many vendors are engaged in discussions and dialogues so that

they can further their own pursuit of China's indigenous technology spend, and they don't wish to be excluded simply for not participating in the dialogue.

So, yes, to answer your question directly, the software could be more rapidly consumed and without license fee or expense. There are certainly concerns around intellectual property protection, but, as I mentioned, a lot of the software pieces that are being used today are already in the open source and public domain.

COMMISSIONER WESSEL: If you're U.S. government user of these services, and I think you talked about all the data centers that are being closed, would you be, if you go to a COTS procurement, a commercial off-the-shelf procurement, strategy, let's say SBA wants to utilize services, goes to buy them on the market, would a Chinese cloud vendor be a vendor in that situation that could be approved by U.S. at this point?

MR. HARDER: So GSA did some very good work with their FedRAMP program and with their Apps.gov platform that describes just the process that you shared out. I do not believe that the Chinese data centers or their systems would meet the test for accreditation today.

COMMISSIONER WESSEL: But there's no prohibition in law that should they meet the test in terms of capabilities, is that it? Or is it because they are a Chinese vendor that they wouldn't be accredited?

MR. HARDER: From a lay person's perspective, I'm not aware of any limitations that would preclude them as long as they can meet the test for certification.

COMMISSIONER WESSEL: They could be a certified vendor of some sort.

MR. HARDER: Yes.

COMMISSIONER WESSEL: Okay. If there's a second round. Thank you.

CHAIRMAN SHEA: Am I up?

HEARING CO-CHAIR GOODWIN: Yes. Chairman Shea. Sorry.

CHAIRMAN SHEA: No, I'm enjoying this panel so much. It's making me comfortably numb.

[Laughter.]

CHAIRMAN SHEA: I'll quote another Pink Floyd line, "We don't need no thought control." So that leads me to a question for Mr. Harder. Is it your understanding that the Chinese leadership views cloud computing as a potential means of promoting internal stability and security? I mean as I understand cloud computing, you basically centralize all the information that's being used into a single place, and they would have presumably control over that box where the cloud exists.

But is this viewed as an internal security, way to promote internal security?

MR. HARDER: Chairman, thank you for your question.

Your understanding of cloud technology--

CHAIRMAN SHEA: Very rudimentary.

MR. HARDER: --is accurate. I think about it as nothing more than an aggregation of many resources down to much smaller but effective pools that can be used. When you start to shrink the points of management, that means those points of management are open for additional censorship and for additional control.

While I don't believe that there has been any stated purpose for leveraging cloud for censorship or control, the technology certainly exists to exploit it just for those purposes.

CHAIRMAN SHEA: But you've never seen anything in the literature about it

being used as a means for internal?

MR. HARDER: I have not, no.

CHAIRMAN SHEA: But repeat what you said in your testimony about doubling the advanced persistent threat, which is one of those phrases people, cyber warriors use, but could you explain what you mean there?

MR. HARDER: A single system that's being built in Chongqing right now, should those resources be aggregated for national strategic pursuits of China, has the ability to potentially double the size and the shape of the advanced persistent threat to our national critical infrastructure.

CHAIRMAN SHEA: Define advanced persistent threat.

MR. HARDER: Sure.

CHAIRMAN SHEA: And it's a term of art.

MR. HARDER: I know that the committee has received extensive testimony on the state of our cyber warfare posture. I think about the potential threat that's being constructed in China's cloud computing platform as the ability to amplify how many different views are attempting to come and touch our critical resource domain.

You can measure that based on the number of network ports that are being created. You could measure that, as my colleague might, in the number of processors that are available for such purposes. I think about it as a general computing infrastructure that could be used for purposes of good or be used for purposes of other national strategic gains.

CHAIRMAN SHEA: So the Chinese want cloud computing as an export industry. They're pretty clear about that. You suggest that there are internal security applications with robust cloud computing capability; right?

MR. HARDER: Yes.

CHAIRMAN SHEA: And it increases the potential threat to the national security of the United States?

MR. HARDER: That's correct.

CHAIRMAN SHEA: Okay. This facility you described in Chongqing is being built in part by IBM; right?

MR. HARDER: That's correct.

CHAIRMAN SHEA: Should U.S. companies be involved in supporting the cloud computing industry of China?

MR. HARDER: Much like many individuals, much like other industries, I think there is the potential for technology to have dual-use purpose, and we need to carefully think about how technology is being deployed.

CHAIRMAN SHEA: I'll close here. I really appreciate the clarity with which you have provided this information.

To what extent are Western companies in the aggregate supporting the cloud computing industry of China?

MR. HARDER: In May of 2007, there were really only two firms that were working on cloud computing as you would understand it today. Today there's about 200, and I would say a very high percentage of them either have footprints today in China or desire to have one.

CHAIRMAN SHEA: Thank you very much.

HEARING CO-CHAIR GOODWIN: Since Chairman Shea has thrown down the gauntlet on Pink Floyd references, I would assume Commissioner Bartholomew will make

some reference to the "Dark Side of the Moon" in her question.

[Laughter.]

COMMISSIONER BARTHOLOMEW: Thanks, yeah.

Gentlemen, this is really interesting, and I actually would like to commend you all for being able to talk about technical issues in a way that a non-technical audience can understand it. It's a talent that not a whole lot of engineers and scientists have.

Dr. Joseph, I think the only thing you and I share in terms of academic background is we're both Golden Gophers.

[Laughter.]

COMMISSIONER BARTHOLOMEW: But I come from that social science background, which was sort of slammed earlier today, and Dr. Simon, I was greatly relieved, since people are talking about Pink Floyd, that when you said you were going to say something maybe not right for this audience, you were going to be talking about sparse matrix algorithms, and it was kind of relief that Pink Floyd was what you were talking about.

I want to follow up one thing from Commissioner Shea, which is this issue of censorship. If China wants to become this net exporter of cloud services, I'm presuming that means that they could become a net exporter of censorship also. Is that correct?

Mr. Harder, you're our cloud expert.

MR. HARDER: Thank you for your question, Commissioner. I wasn't sure where it was directed.

You know, I'm not sure that I would make that leap. I think that the technology, as it sits today, is really designed for large-scale application hosting. It's designed to help lower the barrier of entry for new applications and new ideas to be brought to market.

Any data that goes into the system, whether it would originate indigenously from China or whether it would originate from outside of its Great Firewall, the idea that once the content goes in, there is risk for how it could be used, and whether that risk is in censorship or whether that's in theft of intellectual property, or if that's in simply just not protecting it correctly, those risks, in fact, do exist today.

COMMISSIONER BARTHOLOMEW: Okay. I'd like to shift gears a little bit, and for all of you, I'm trying to understand how in terms of the U.S. supercomputers, how have they been funded? Are most of them in the hands of private corporations now? How does our supercomputer industry work?

DR. JOSEPH: Sure. So I can speak to that to begin with. For the very high end of the supercomputer market, it's primarily federally funded, and that can be either through government agencies or some of the major academic institutions that really get their funding from various government agencies like the National Science Foundation.

Industry in the U.S. has been very much a leading user of supercomputers also, but not of the same gigantic caliber. So, for example, Ford Motor Company has led the automotive industry in its use of HPC for the last 25 years, and in the last few years, it's actually fallen behind because of the recessionary pressures that they had. Other automotive manufacturers in Japan, Korea and Europe, in particular, are trying to put the U.S. vendors out of business. They see that we're weak so now is the time, and

so they're using supercomputing to help do that.

And then in the academic sector, you also see a fair amount of purchases. The second chart in the attachment I have here actually splits out by the different sectors. So you have the bio-life sciences. CAE is manufacturing, computer aided engineering primarily, and you can see that it's really split quite a bit across the board, and I'd be glad to send you the same chart for just U.S. purchases. We track that also.

But National Labs and the government are very large. The other area that's very large is what we call classified/defense, which would include things like national security applications, and they represent on the order of around 20, 25 percent of a lot of purchases because many of those purchases are spread across universities and other places, too.

COMMISSIONER BARTHOLOMEW: And is some of the expertise, in a company like IBM, has some of that been based on funding that was provided by the federal government somewhere along the way?

DR. JOSEPH: Very much so. In fact, in the last ten years, one program alone by DARPA, called the HPCS, or High Performance Productivity Computing Systems Program, provided funds to IBM and Cray at the end, and originally five different companies, as they competed for the product. The final funding of phase three was roughly $250 million to IBM and roughly the same amount of money to Cray.

So if you look at Cray's financial statements, for the last six years, their R&D is a significant percent of revenue, on the order of 35, 45 percent. The lion's share of that was all paid for by the U.S. government.

COMMISSIONER BARTHOLOMEW: So do we have to worry, going back to what Chairman Shea mentioned, sort of about what IBM is doing helping China?

DR. JOSEPH: Okay. So first of all, I'd like to address that question.

COMMISSIONER BARTHOLOMEW: Yeah.

DR. JOSEPH: IBM is not helping, in my opinion, helping China, quote, "create a cloud for any kind of purposes other than selling them parts." So I would suggest not to impose any limitations on U.S. manufacturers selling equipment to China because for jobs, economic growth, we want to sell more American products.

If we were to put restrictions on IBM, HP, or the other providers, which China is already afraid of, and they have their own internal development, they'll just build the processors themselves so we'll lose the economic value on that.

The key part of what is going on is how China will be using their cloud environments, and in the last, in my handout, on the last table, there's an interesting chart. I don't know if you had a chance to look at that. On China's largest supercomputer, they have a graduate school program on breaking passwords. So they actually have a graduate college that teaches this as a coursework, and as a winner you get to run your version of your password breaking program on their largest supercomputer.

And if you see here, on the first sub-bullet there, the last chart on the handout, when they ran it on just one node of their computer, they could break 50,000 passwords a second. Now when they activated this new technology called GPUs, NVIDIA accelerators, on that same one node, they could break 250,000 passwords per second.

COMMISSIONER BARTHOLOMEW: Jeez.

DR. JOSEPH: But the big part of it then is, well, what do you do when you run it on the whole supercomputer? So when you run it on this gigantic machine, they

can break--and you'll see the last bullet there--1.8 billion passwords a second.

If you're concerned about what China could do with cloud or with data coming in, it's much more around the software and the usage of it.

So to restrict U.S. vendors from selling them the components is just hurting the U.S. economically. China will just build the parts themselves or buy them elsewhere. It's all about the usage of the machines.

So the reason I included this chart is not only to show they have the capability, but they are also going around bragging about it. This came from supercomputing conferences and they're public presentations.

COMMISSIONER BARTHOLOMEW: I'm floored.

DR. H. SIMON: Could I add something to your earlier question concerning the U.S. government investment? So one element I wanted to point out is I think in 1991 or 1992, Congress passed the High Performance Computing Communication Initiative, and it's often forgotten that this was a significant investment in the technology that we all benefit today, and I think this is very important to remember.

At that time, it was about a doubling of funding for technologies that we take today for granted. So any large cluster that is being built anywhere in the world in terms of whatever Google and Microsoft are using, or even the Chinese are using, it's based on technology that was developed in the early '90s under federal government funding.

It also had another effect; specifically in high performance computing, I believe the significant investment in U.S. companies and giving U.S. companies additional incentive to develop new technologies, I believe, put the Japanese supercomputing vendors out of business. I mean they still are around, but over the last ten or 15 years, they have been barely hanging on there.

And so in ways, the U.S. government investment created the industry, created the infrastructure here that is still far and above anybody else in the world.

COMMISSIONER BARTHOLOMEW: Okay. Thank you.

HEARING CO-CHAIR GOODWIN: Commissioner Reinsch.

VICE CHAIRMAN REINSCH: Thanks. I was just saying to Commissioner Wessel, your last comments, if nothing else, for the skeptics in the audience, I think are evidence that we can pick winners. Keeping them is a different story. But we have a long history, I think, of identifying critical industries and then providing appropriate support. But that's not what I want to talk about.

Mr. Harder, first, on the cloud side, it sounds if this continues to grow as you've implied, cloud services are going to become kind of a commodity, widely available and widely used by lots and lots of different companies, individuals, whatever.

If I ran a company and were in the market for cloud services, why would I be interested in China? What would make their services more attractive than some other vendor? Is this just a price issue or what else is going to be a factor?

MR. HARDER: Thank you for your question, Commissioner.

In fact, I think there would be some benefit for organizations who want to house their cloud computing assets in the country of China for any of the joint venture work that is occurring there. There would be a cost benefit for having it in region, but--

VICE CHAIRMAN REINSCH: Why? I thought the concept of the cloud was that location didn't make any difference?

MR. HARDER: Location makes a difference in terms of performance. For

many applications, the idea of locality, the closer you are to the data, the faster you can run your operation against it.

But to answer your question specifically, it's unclear that cost alone is going to be the concept that's going to force data to move over there. There are many providers of cloud computing in the United States today that are providing the services for barely over the cost of their electricity. So, unless China offers a uniquely different cost profile, it's unclear what additional would be used to attract placing the data elements there.

VICE CHAIRMAN REINSCH: So I would mostly be interested in going there if I thought there were some local benefit?

MR. HARDER: If there was some local benefit. More to the point, if I was an indigenous consumer, if I was a local Chinese consumer, I now have a platform that is available to me with limited, limited price, limited expense. If I have a good idea that helps me bring it to market faster, I don't have to ship that idea off to the United States to do it. And I can do this with, again, very limited economic commitment.

I think it's a unique approach that the government is trying to, building such a large computing infrastructure for these purposes, where in the United States, it's entirely, at least at this point, the services that are being offered are more from a commercial perspective.

VICE CHAIRMAN REINSCH: Well, yeah, I think it would be more market driven. That's why I'm trying to figure out, they're creating enormous capacity, and no doubt they'll suck a lot of that up with domestic use, but if they want to go into the-- I'm trying to figure out what the threat is--if they're trying to go into the exporting business, as you said, it seems to me they have to offer something that's attractive, and you laid out in your testimony a number of reasons to be skeptical of the services that they provide for a variety of reasons.

I just don't understand why it's going to be that attractive an offer compared to what would be available domestically.

MR. HARDER: Well, you heard testimony from other colleagues today that talked about how a single node in a system like this has the ability to crack 250,000 passwords per second or per minute. Imagine a physical computing warehouse the size of the Pentagon that does nothing but that. This is the potential of cloud computing in China.

VICE CHAIRMAN REINSCH: Yeah. I was going to ask about the password just out of curiosity. I'm not sure what the immediate application of something of that volume is. So I have 1.8 billion broken passwords. What do I do with them?

DR. JOSEPH: Right. So part of the issue here is, it very clearly is being used for being able to read people's files. We visit China very frequently and all the other sites around the world. The amazing part to us, we visit the vendors providing it, the people installing it, and the people using the machines, and in China, the fact of the government watching what you're doing, censoring what Web sites you go to, is viewed as a normal thing. A good citizen does not go to a bad Web site.

And the fact that the government tracks that is a very normal thing in the culture there. There's a very big cultural difference. So the ability to get into people's passwords is actually viewed as an appropriate behavior by the government within the country.

So this is a very substantial and, quote, "appropriate" type of thing to train

people in a graduate program, and that's why they actually have courses on that, to train people to break passwords so that they can actually read protected files.

VICE CHAIRMAN REINSCH: I think I'd like to--I think I want to pursue that, but I think it would take too long. So I'll save, wait for the next round.

DR. JOSEPH: Okay.

VICE CHAIRMAN REINSCH: Thanks.

HEARING CO-CHAIR GOODWIN: Commissioner D'Amato.

COMMISSIONER D'AMATO: Thank you, Mr. Chairman. Thank the panel for I would say a frightening presentation in some ways, but very, very interesting.

I think there's an Elvis Presley song that--

[Laughter.]

COMMISSIONER D'AMATO: No, but I won't--

VICE CHAIRMAN REINSCH: You're showing your age.

[Laughter.]

COMMISSIONER D'AMATO: I just want to clarify in my mind what we're talking about here with this cloud and the impact it may have on our national security. For some reason we selected the Pentagon as the place that is the size that this would go into. Maybe that's not appropriate or anything. But is it true that the size of this new facility gives the Chinese a new capability from the point of view of national security simply because of the size and the power that might be associated with the synergistic capacities that are all in one place?

Is that true, and if it is true, do we have a way to measure that and a way to determine what we can do to combat any negative influences or a cyber attack or whatever it is we're talking about in terms of its impact on our infrastructure in the United States? Does that make sense? Does that question make sense? Do we need to be worried about this and the size for our national security basically is my question? Or does it matter?

MR. HARDER: The next closest sized building that I could find to use for the analogy or for comparison was the Merchandise Mart in Chicago. So it was the Merchandise Mart or the Pentagon as a scale reference.

It's unclear. We certainly have the capacity and have the ability to measure in terms of the computing infrastructure what it means in terms of its available capacity, and certainly can postulate in terms of the applications that could be run on top of it. I think that can be done with limited academic work, in fact.

Should there be cause for concern about what a system like this could deliver? My remark to you would be absolutely. And what is the response? What could be an asymmetric response to it, in fact? I think that we need to begin looking at building some of these sized and scaled systems on our own as well.

They can be done in the context of the research computing environments. It could be adjuncts to the high performance computer environments that are available at the national level today. We need to further our investment in cloud computing, not just for the sake of commerce, but for the sake of national security.

COMMISSIONER D'AMATO: So not to be alarmist, but to take it to this step, if this could be a new capability because of its size and its relationships, the synergistics of its components, in some ways it could be considered a weapon, and it might be useful to try and determine what the range of capabilities of such a capacity might be. How to measure it? How to determine it? Would you agree that that sounds

reasonable?

MR. HARDER: I don't have an opinion on that, sir.

COMMISSIONER D'AMATO: I think it's an open question.

MR. HARDER: Yeah.

COMMISSIONER D'AMATO: Thank you, Mr. Chairman.

HEARING CO-CHAIR GOODWIN: Commissioner Cleveland.

COMMISSIONER CLEVELAND: I'm just relieved, Dr. Simon, that you did include your research interest because I'm the person in my office that still believes computers function by little hamsters and wheels, and so I actually just sent my boss an e-mail and said you won't believe, I'm sitting here listening to somebody whose expertise is in sparse matrix algorithms and large- scale--I can value--problems.

So understanding that I'm the hamster wheel person, I'm interested in what you put in your written testimony about human capital, and in a field such as supercomputing with rapid technology change and the need for large team work and multidisciplinary collaboration, an academic structure seems to be a barrier to progress.

And while you put this in the context of personal observation, could you talk a little bit about--we've heard about the threat side of this--what are the constraints in terms of Chinese capacity to move into this field aggressively?

DR. H. SIMON: Yes. So I mean this is based on a personal observation, but I was actually surprised to hear this in this morning's testimony when we talked about the academic environment, that the academic environment in China is still, to use the term that either Dr. Simon or Suttmeier said, Confucian, that is the senior person rules.

This environment doesn't work very well in a field like computing wherein computing technology changes in Moore's Law scale. That is performance doubling every 18 months. And so what somebody has learned in academic career in computing in 1980 is completely outdated.

I don't know how within China this problem is being addressed in the traditional academic setting. However, I'm aware, and this was also discussed this morning, that there is quite a concentrated effort of recruiting national Chinese who have been working in the field in the U.S. to come back and take on leadership positions back in China.

Again, just on a personal anecdote, I visited Peiking University. I met the provost and the dean of engineering. Both had worked in the U.S.--the Dean of Engineering, she had worked at Los Alamos National Labs--have used U.S. supercomputers, and were interested in computational science. It seemed to me this is one of the top ten universities that was also mentioned this morning. I think that pattern repeats itself across China, that researchers who have interest in computation and have American education, and at least experience as visitors or collaborators in America, are pulled back and bring that expertise in what I would say our model of computational science back to China.

COMMISSIONER CLEVELAND: And that would address the language issue that you also--

DR. H. SIMON: Yes.

COMMISSIONER CLEVELAND: --mentioned was a factor?

DR. H. SIMON: Yes. So, again, the language, usually it's just based on attending quite a number of conferences, and I felt that the actual papers often

delivered by Chinese researchers, to say it this way, were not very good, not just because of the language issues, but because they were sort of treading on old ground and very incremental, and not adding very many new things.

COMMISSIONER CLEVELAND: You also point out that while the facilities bear the operational costs, they're charging for use of their supercomputer capacity, and that this might be a barrier because academics can't actually use it because of the expense, and they'd rather stay on their smaller local systems. Can you elaborate on that?

DR. H. SIMON: That was, again, an observation based on conversations I had recently. The Tianjin Center, the number one center, is supported by the region or by the city, but only the acquisition was supported. They have to raise their operations costs, which can be substantial for these large centers, by charging for access to the centers.

Charging access for the centers may be fine for an oil company or for an animation company, but when you come as an academic researcher, and you have to actually pay to use one of those biggest tools, this is a huge barrier, and therefore I think it, at this point, keeps a lot of the educational element away from researchers.

This actually, ironically, was the same situation as we had in the U.S. in the 1980s when most of the supercomputers were in National Labs and academic researchers could not access the supercomputers before the National Science Foundation started the Supercomputing Initiative and put very large supercomputers into universities and started a program of educating scientists in using supercomputers in academia. So it may change, but currently I would see it as a big barrier.

COMMISSIONER CLEVELAND: Okay. And, Mr. Harder, this is probably a really stupid question so bear with me.

COMMISSIONER WESSEL: Yes, they feed the hamsters.

COMMISSIONER CLEVELAND: They feed the hamsters.

[Laughter.]

COMMISSIONER CLEVELAND: Thank you.

COMMISSIONER WESSEL: You're welcome.

COMMISSIONER CLEVELAND: When Commissioner Reinsch asked about what the added value might be of moving to China, can you actually have confidence if I'm a business in the United States, and I go to the Earl Joseph cloud computing service, that he isn't subcontracting to a Chinese facility?

I mean what are the institutional limitations or the technical limitations or restrictions that would be placed on my business proprietary information not being moved because he's at capacity and therefore he's moving it to a different shelf?

And please make it simple because I won't get it otherwise.

MR. HARDER: You raise a very good question. In fact, there are organizations today that are building business models entirely around simply being a broker--

COMMISSIONER CLEVELAND: Right.

MR. HARDER: --between many of the cloud computing services, and in that instance, it would be advantageous to the broker to find the lowest price alternative in a market to source the data. It's unclear as of yet if that is going to be from these Chinese systems or from other market participants.

COMMISSIONER CLEVELAND: But there is no reason it couldn't be from the

Chinese systems?

MR. HARDER: That is correct.

COMMISSIONER CLEVELAND: Okay.

DR. JOSEPH: If I can add to that, the Chinese are actively pursuing brokers for that. In our last visit, they actually asked us if we were interested in doing such a thing and were aware of other companies for that?

VICE CHAIRMAN REINSCH: What did you say?

DR. JOSEPH: It's not the nature of our business. We're a market research company. But we do connect within the supercomputer realm vendors and buyers frequently, and that's the reason they asked the question.

But the whole idea of clouds, I would like to clarify, and that right now in the U.S., there's a number of them. The word "cloud" is being used in many different areas. So I want to use just what we call public clouds, like Amazon, Microsoft and what you're referring to in China.

The whole concept here of a cloud means you don't know where your data is, you don't know where the processing--

COMMISSIONER CLEVELAND: That's what I thought. Yes.

DR. JOSEPH: --and the software is. So the entire model is to perhaps have some stuff in Europe, some in the U.S., some in South America, and so China would fit in just as well, as would Russia or India.

Now, one question you asked is what's China's cost advantage? Building a Pentagon-sized data center, you have to have cheap electricity, you have to have fairly cheap land, and generally cheap cooling, some way of cooling it so could be next to a river or something like that.

But you can also have the national government underwrite some of those costs. So if you have the pervasive cloud model, and let me fast forward five years from now, then whoever is willing to sell those cycles or the storage at the lowest cost will have an advantage in general.

Now, the other issue is performance. In high performance computing or technical computing, clouds are not very popular because these problems need a lot of performance, a lot of bandwidth, and they have massive data. So you can't move your data in big chunks.

But the issue of controlling that, the whole concept of clouds basically is you don't know where it's running, and it could be anywhere.

COMMISSIONER CLEVELAND: I don't feel quite as stupid as I thought coming in. Is there any reason for me to believe that my data is in some domestic safe secure cloud? I mean there's nothing that says that you can't move it someplace else?

DR. JOSEPH: Right. So let me use a couple of personal ones. So iTunes on Macintosh, downloading videos if you'reusing a TV show program, or saving your pictures for backup. You know there's various companies like that. Do you really care where those backup files are? And in many cases, like your pictures, the companies that generally do that will have five different backups of every picture because they have created a way in the system where everyone temporarily holds something so they keep stuff in motion so you have four out of the five backups which don't cost the company anything because they're being temporarily held in staging areas.

So you really don't care really where your pictures are, where you're getting your music from. There's a tremendous amount of data that has a zero security

requirement. And our advice to everyone is, hey, that's great stuff for the cloud. If you have a security issue with your data, you better think very carefully and write unique contracts.

And companies like Microsoft and Amazon will write specific contracts. We do a lot of work with oil/gas industry. So for British Petroleum or, you know, a Shell Oil, if they're doing exploratory work in Saudi Arabia, Egypt, that data has to stay in the country, and if they ever let that data go out of the country, they lose the right to even explore for oil there. So you're talking massive business reasons.

So there are some cloud providers that are starting to say all the data will stay in a certain country because there's business reasons for it. So we expect five years from now for you to have a whole list of options. In other words, if you say I want my data to always stay in the U.S., you click that box--all ones that cost you 20 percent extra, but literally you'll have those types of options.

And when you were mentioning the software solutions and all the pieces being put into place, we think all those pieces will be in place, and it will be just as easy as checking a box to guarantee it. But every box you check will cost extra.

HEARING CO-CHAIR GOODWIN: Thank you, Doctor.

COMMISSIONER CLEVELAND: Okay.

HEARING CO-CHAIR GOODWIN: Bit of a compressed timeframe here, but we have several folks who want to ask a second round of questions starting with Commissioner Bartholomew.

COMMISSIONER BARTHOLOMEW: Thanks very much.

Gosh, the more you guys have spoken, the more concerned I get. Mr. Harder, I want to go back to this question of sort of cloud and who controls it, but one of the things that the Chinese government has done as it's developed industries, is that it has sort of required technology transfer or use of Chinese products or something like that.

Can you envision that China would insist that U.S. companies doing business in China would have to use the Chinese cloud?

MR. HARDER: No, I do not. What I see today is an interest and a desire from China to construct these clouds and understand that some of them are just now getting underway. The way that they're doing that is they're sourcing community and open sourced software components and buying a little bit of software from U.S. based firms.

As you heard in the testimony earlier today, the joint venture laws on establishing a business in China are very explicit, and the amount of IP that gets transferred through them is voluminous. I don't know if they'd want to further push the envelope and probably a bit far afield for me to comment on.

COMMISSIONER BARTHOLOMEW: Okay. And Dr. Joseph, you mentioned that the Chinese are trying to work with brokers already. Could brokers be directed toward certain sectors or certain industries to target in order to try to get that data on to the clouds controlled by the Chinese?

DR. JOSEPH: The most successful ones right now are very targeted to an individual industry. The reason for that was brought up too: the software issue on this. So one problem with the cloud is the right software is sitting on the cloud that you need to operate. So, for example, the oil/gas industry has its own separate brokerage companies. The bio-life sciences, very different software.

And there's a number of companies trying to do it for different manufacturing segments. And the biggest reason around it is each one of these segments need different types of software packages, and the cloud tries to make it invisible what software you're using, but also the cloud needs to be shaped and marketed and advertised in a language that people understand. So to answer your question, that's the absolute direction this is moving.

COMMISSIONER BARTHOLOMEW: Yeah. I guess what I'm thinking about is if the Chinese have not been able to get access to certain kinds of IP in this country through acquisition, purchase, JV, regular theft, getting through passwords, should we be concerned that they might be targeting certain sectors to get the data up in the cloud and then accessing that data in the cloud? It could be another way that they could get access to proprietary information they might not otherwise be able to get.

DR. JOSEPH: Right. I think it's a potential problem, but I would guess that the Chinese, at least the folks that we've been talking to, will first target it where they see the biggest economic value. So they're going to try to sell it as a service, and it will be industries they're interested in.

So, for example, this morning, there was discussion that the Chinese are very interested in getting into the aerospace, the commercial aero programs. So we could see them targeting that sector to begin with.

COMMISSIONER BARTHOLOMEW: Okay.

DR. JOSEPH: So, yes, it's a potential.

COMMISSIONER BARTHOLOMEW: Thank you.

HEARING CO-CHAIR GOODWIN: Commissioner Reinsch.

VICE CHAIRMAN REINSCH: One of the issues making its way through the trade policy community right now that we keep running into in trade negotiations is forced localization, particularly of these kinds of services.

This is a particularly big problem for the financial services sector for obvious reasons, namely, economies of scale. So far the United States government has taken the position that forced localization is a trade barrier.

It's basically a performance requirement in a 21st century context, and it's something that the administration, both of the last two, have opposed, as has the American business community urged them to oppose it. I can't help but think, though, that if countries were to do that, it might address some of the security problems that you've suggested.

How do you guys feel about forced localization requirements?

DR. JOSEPH: Well, I'll start. I believe free trade is the best way because my concern would be if we try to make enforcements, China will naturally use that to their advantage to do the same thing against our companies. China is developing backup plans in case the U.S. or Europe does take those types of protectionism actions against them.

And, for example, that's why they have their own processor development things. They're concerned that at some point in time the U.S. will say they can't have the leading-edge processors. But in all different aspects, my biggest concern is China would apply those back to us as fast as could be.

VICE CHAIRMAN REINSCH: Anybody else want to comment? You don't have to.

MR. HARDER: I believe in free and unencumbered trade, and putting more

barriers in place in order to achieve that is something that I wouldn't support.

COMMISSIONER WESSEL: Are you asking us, too?

VICE CHAIRMAN REINSCH: No, I was not asking. Specifically, I wasn't asking you.

Dr. Simon, let me go back to something you said early on in your testimony, which was that--I think it oversimplifies--that the software is more important than the hardware in many respects.

When I was in the government, we came to that conclusion. One of the last things that President Clinton did when he submitted his High Performance Computing report in January of '01 was to recommend de-control of the hardware and stricter controls on certain software, a recommendation the next administration ignored completely.

But you also pointed out that we're lagging in the development of software for high performance computing, I think that's what you said. Can you elaborate on that? What's going on on the software side in HPCs?

DR. H. SIMON: So let me first correct. I think that developing software for high performance computing platforms and supercomputers is a very big challenge, and I think we still haven't even, with a lot of research in the last 15 years in the U.S., solved all the problems.

But I think, just to make this clear, that the U.S. software developments, particular in application software but also in systems software and tools, are by far ahead of the rest of the world, and so we have a unique capability that is not present anywhere else.

Our European colleagues and our Japanese colleagues in many cases take tools and software that is available to them for at least scientific application purposes.

VICE CHAIRMAN REINSCH: But I thought you said earlier--that's sort of saying everything is fine, but I inferred from your earlier remarks that everything is not fine.

DR. H. SIMON: Well, the problem that we have, and like the rest of the world has, is that technology is rapidly changing, and to introduce yet another term we haven't talked about yet, the next level of high performance computing is exascale. As we move to exascale, and this is a level of performance that may come by about 2020 or so, fundamentally, the technologies in high performance computing will change.

The big challenge is that as we build these larger and larger systems--one of the big challenges--is that the power consumption goes up, and building systems that are much more energy efficient is a big challenge. In order to get much more energy efficient systems, the fundamental system architecture has to change, and consequently the software and the way these systems will be used has to change.

So this is a very big shift, and this is a big challenge over the next four or five years. There are research programs in place to address those changes that will happen, but these changes create an opportunity for other players, like China, and the change very simply is this is the old example of countries that didn't have a landline phone infrastructure went right away to cell phones.

We have the same situation in high performance computing. As we move into this new era of high performance computing that involves technologies such as multi-core, many-core platforms, somebody who has not developed for these technologies can just--who has not developed supercomputing software in the past can

jump right to the next generation and build software for the next generation.

And I think this is the big opportunity that a country like China with great determination could capture. I'm just saying it's hypothetical. I don't know if it's actually happening, but it is, in a sense, a concern, and I'm glad you gave me the opportunity to elaborate on this concern. That's the concern that I was harkening back to the HPCC legislation in the 1990s. This is the missing piece. We just don't have at this point a forward-looking program that addresses the potential gap in exascale computing.

VICE CHAIRMAN REINSCH: Thank you.

DR. JOSEPH: Could I add just one point to that, too? So on the higher end of software, we have quite a bit of leadership, but if you look at all the technical software programs that are being run today, 25 percent only run on one or two cores, and if you go up to eight cores, which is one little node, that's almost 50 percent of all software being run on technical computers.

So when I mentioned there's a very large gap there and an opportunity to move that to more scale, that's kind of where a lot of codes are stuck right now.

HEARING CO-CHAIR GOODWIN: Chairman Shea.

COMMISSIONER CLEVELAND: What does that mean?

COMMISSIONER BARTHOLOMEW: You lost us on that one.

CHAIRMAN SHEA: Just a quick question for Mr. Harder. In the Five Year Plan, the 12th Five Year Plan specifically mentions the need to develop cloud computing capabilities as a sub-industry of next generation IT. Who are the major players in China that are implementing that policy?

MR. HARDER: From a commercial perspective?

CHAIRMAN SHEA: Commercial perspective.

MR. HARDER: China Unicom, Huawei and ZTE.

CHAIRMAN SHEA: Those are the three. Baidu?

MR. HARDER: Baidu is a benefit. Baidu enjoys the benefit of cloud computing. I wouldn't identify them as an innovator or as a leader in the technology.

CHAIRMAN SHEA: Okay. Thank you.

Supercomputing. This is supercomputing 101 here. What are the main applications that the United States uses its supercomputers for? What are the main applications that the Chinese use their supercomputers for? And how do we in the United States figure out who gets to use the supercomputer and how in China do they figure out who gets to use the supercomputer?

DR. JOSEPH: Want me to start? So some of the main applications are the same. So let me start with the ones for humanity, and that is weather forecasting to avoid storms, earthquakes and natural disasters, and most nations use supercomputers for that for obvious reasons. Part of the obvious reason, though, is for helping you grow better crops, so for forecasting weather, rain patterns and everything else.

The next other major area is for national defense. Now making codes and breaking codes are one area, but if you look at any defense item, whether it's today a rifle, a tank, an aircraft or a missile, anything, supercomputers are used for designing, testing, and making those better.

But they're not just used to make the device better. They're making them to use better in the battlefield so a simulation where you're actually fighting somebody else in a real type of environment with real equipment or equipment that's never been

made before.

Another area is in the financial community, and that is to figure out how to make more money, so real-time trading, understanding what's going on in the stock markets is very common.

The other one is manufacturing so designing everything from your iPad, your cell phone, car, motorcycle, blenders, washing machines, you know, just all across all manufactured projects. The U.S. Council on Competitiveness has a great quote, and that is "to outcompete is to outcompute." I mean "to outcompute is required to outcompete."

And what they were saying about that is going forward the companies that use the most HPC will have the better products and will be most successful, and we're seeing that across the board.

Another sector is oil and gas. That's to find where oil is and figure out better ways to get it out of a reservoir. So there are two primary applications there.

In the bio-life sciences, it's everything from designing new drugs, trying to test them in advance, the whole genomic things, customize drugs for people. Understanding how the body really works is a major medical area. So that's a handful.

CHAIRMAN SHEA: Do the Chinese use their supercomputers for applications that we don't use or vice versa?

DR. JOSEPH: Okay. So China is almost the same as U.S. in most of those areas, whereas, China has a couple of other things that they do that we frankly don't do. Because the way the money works in China, the national government gives some money, but the cities provide a lot of the money. They do a lot of localized forecasting.

For example, in Beijing, the weather can be very smoggy and dangerous. So to have your high school soccer game Thursday night versus Friday night, they will do a weather forecast to determine which is the safer night to have the high school soccer game.

It's something that all the city planners understand and everyone else does. They also use it for extensive traffic, realtime traffic monitoring and traffic control of stoplights and so on and routing of ambulance services. So they use it much more on a city localized basis than we do in that regard.

The other area that we see in China is we refer to China as the most practical users of technical computing, and in that sense, they buy exactly the machine they need for that purpose, and whether it's in the factory or wherever, it's that incremental innovation, and they do much better at using it for incremental innovation.

DR. H. SIMON: So maybe I can answer the second part of the question because I don't have anything to add to what Earl said.

The second part of the question was who gets access to supercomputers and how is this controlled? So in the U.S., you can very simply say if the systems are being acquired by, of course, a private company, then mostly just the researchers and users in the company will use that in aerospace or in oil or gas.

We have the National Science Foundation supporting supercomputers, large and mid-range supercomputers, across different campuses. Large computers are accessible to the whole academic community in the U.S. This is a program that has been going on for many, many years, and as I pointed out previously, it's very important for building human capital in supercomputing.

The Department of Energy, Department of Defense are the other big users

and consumers of supercomputers. They buy the systems for use in the National Labs for their mission specific applications. In DOE, for example, we use our supercomputer in Berkeley for a large number of energy applications.

Our colleagues in the NSA, this is for nuclear weapons modeling. Those systems are if they are on classified projects, of course, restricted to users who have access, but we also have several of the DOE machines out in the open, especially the systems at Argonne, Oak Ridge and in Berkeley, that can be shared with the national user community where access is given for challenging scientific projects on the basis of writing a good proposal.

CHAIRMAN SHEA: Thank you.

HEARING CO-CHAIR GOODWIN: We're already about five minutes over, but I know Commissioner Wessel was indicating one question, and if we can do it quickly. Okay.

COMMISSIONER WESSEL: I only have an hour of questions, but that's okay.

HEARING CO-CHAIR GOODWIN: A 12-part question.

COMMISSIONER WESSEL: Twelve-part question, which I'll get through in five minutes, but it may take you an hour to answer. Actually part of this is if the witnesses would be willing to answer some questions on the record later on in writing because I think a lot of us have questions we'd like to ask?

I have two relatively quick questions. Following up on Commissioner Bartholomew's question about the potential for cloud computing to be used for reasons that we may not necessarily appreciate. Let's take Facebook, and while I understand the proximity to your storage, the speed at which it's accessed is important, et cetera, if Facebook were to move all of their cloud computing, all of their storage, et cetera, to China, and you were to couple that with the ability to crack everyone's code who is using Facebook, 900 million, probably take a couple of seconds, they'd have access and they potentially could, because you have very few pipes that are coming out of the cloud computing, you could restrict access to data.

The Chinese could choose to do that should they want to. I'm not saying they will, but the storage and the control of both the information and the computing coupled with the ability to access that data does provide a potent tool that could be used to restrict access, to stop certain transmissions from going forward, so the Jasmine Spring, a number of other things, that might have gone to fruition. Is that correct?

MR. HARDER: I think you highlighted a number of technologies that would require orchestration in order to achieve that.

COMMISSIONER WESSEL: Understand.

MR. HARDER: The bandwidth at the carrier level, the storage at the storage level, and the compute resources, but you're correct in your assumption, that if those pieces were orchestrated, that access to the content could be restricted.

COMMISSIONER WESSEL: Okay. Thank you.

Second of all, and to go from Commissioner Reinsch's question in a different way--and I understand the strong support for free trade on the panel--we now have labeling. You know, you pick up a product that says "Made in China." Do you have any problem having a label that says "Stored in China"?

COMMISSIONER BARTHOLOMEW: What would you put it on?

COMMISSIONER WESSEL: I'd put it on maybe on the contract you sign so

that a consumer has a right to know where their data is being stored should they choose to store, you know, that they have a concern about, they can do it elsewhere.

MR. HARDER: That's an interesting question and one that I'd like to carefully consider for the panel.

COMMISSIONER WESSEL: Okay. I'll do the rest in writing later on. Thank you.

HEARING CO-CHAIR GOODWIN: Gentlemen, thank you very much. I've been sitting here for the past five minutes trying to come up with a very witty way to incorporate "another brick in the wall"--

[Laughter.]

HEARING CO-CHAIR GOODWIN: --into our closing, but I won't do that.

Thank you again. We're going to take a ten minute break.

[Whereupon, a short recess was taken.]

PANEL IV: DEFENSE SECTOR INNOVATION

CHAIRMAN SHEA: If we could begin the last panel now, appreciate everyone sitting down.

Our final panel today will examine innovation in China's defense sector. Dr. Thomas Mahnken, our first panelist, is a professor at the U.S. Naval War College and a visiting scholar at the School of Advanced International Studies at the Johns Hopkins University. A former Deputy Assistant Secretary of Defense, Dr. Mahnken has also published widely on technology, strategy and war.

Our second panelist, Ms. Kathleen Walsh, is Associate Professor of National Security Affairs, also at the U.S. Naval War College. She has researched and led several recent projects on China's S&T activities and is a member of several Asia and China-related professional organizations.

We welcome you both here. Professor Walsh, you have testified before so you know the drill--seven minutes, please. But we'll begin with Dr. Mahnken.

STATEMENT OF DR. THOMAS MAHNKEN
PROFESSOR OF STRATEGY, U.S. NAVAL WAR COLLEGE

DR. MAHNKEN: Thank you very much, Mr. Chairman, for giving me the opportunity to appear before you today.

You have my written testimony so what I'd really like to do in the time that I have for spoken remarks is just to highlight a couple of key points.

The topic of Chinese military innovation is a very important one, both just in assessing China's military capabilities, but also I think in helping the United States and others guard against surprise. Military innovation has historically been a source of advantage on the battlefield and also strategic surprise, and the cases are many throughout history.

It's important for us to understand the scope and pace of Chinese military modernization. We want to avoid the danger of overestimating the extent of Chinese military modernization, of crediting China with capabilities that it doesn't possess, but at the same time, we don't want to underestimate Chinese military modernization for to do so would open the United States and other regional actors up to surprise.

This is obviously a topic of considerable recent importance, and certainly statements from U.S. leaders past and present would seem to indicate that, you know, we have generally underestimated the scope and pace of Chinese military modernization.

That having been said, innovation-defense innovation is a diverse phenomenon. I think when we use the word "innovation," we use it as a term that covers, often covers, very, very different things.

So what I've tried to do in my prepared statement is give you some ways to think about innovations, and this work draws very heavily on work that I've done with Kate and with Pete Suttmeier and with others, largely part of UC-San Diego's Minerva Research Institute grant on defense science and technology in China.

When we talk about innovation, we can be talking about anything from basic imitation of weapons and systems that other militaries have, to the development of genuinely novel capabilities. We can be talking about the development of new hardware, but also the development of new processes and organizations, and we can be talking about the development of fairly simple things, but also very complex.

And I think if you look at the universe of what the Chinese military has done, like most militaries, it's tended towards small-scale innovation. Of course, the U.S. national security community cares most about innovations with the potential for high-end or disruptive innovation.

And I think we see some of that as well, particularly when it comes to the Chinese ballistic missile program and offshoots from that, including the ASAT, their ASAT program, to a lesser extent, in their military aircraft program, and some of their naval systems as well.

So while there is a lot of incremental innovation going on in China, I also see substantial evidence for some larger-scale and more disruptive innovation.

Another way to think about innovation is in terms of the process, and there I think we've tended to see the outputs of innovation. We've tended to see new weapon systems as they are fairly far along in their development because of Chinese

opacity and so forth.

As a result, I think we have tended to be surprised by programs that I think in retrospect we will learn have been entrained for some time.

So I have provided in my written testimony some ways to think about the process of innovation, some of the indicators that we may see, and then I just concluded with some recommendations. Those recommendations really center around things that we can do to build up our intellectual capacity for trying to understand Chinese military innovation because as I look at academia, as I look at government, I think we're doing a better job than we have in the past in trying to understand Chinese military modernization.

But if I look at it in comparison to where we were say in the past and thinking about Russia and the Soviet Union or other advanced militaries, we still have ways a go in building the types of intellectual capital that we need to really understand what's going on in China, and with that I'll just conclude my opening statement and look forward to your questions.

PREPARED STATEMENT OF DR. THOMAS MAHNKEN
PROFESSOR OF STRATEGY, U.S. NAVAL WAR COLLEGE

Thomas G. Mahnken
Jerome E. Levy Chair of Economic Geography and National Security
U.S. Naval War College

Testimony Before the U.S.-China Economic and Security Review Commission

Hearing on Chinese Innovation: Implications for the United States

Thursday, May 10, 2012

Thank you for giving me the opportunity to testify before the Commission on this important topic.

At the outset, I would note that I am testifying here today in a private capacity, and that any views expressed are mine alone. That having been said, I would also like to acknowledge that outstanding work that is going on under the leadership of Tai Ming Cheung of the University of California's Institute for Global Conflict and Cooperation. Specifically, I would like to single out the center's Project on the Study of Innovation and Technology in China (SITC), which has been funded by a grant from the Department of Defense's Minerva Research Initiative. Participation in SITC and collaboration with Prof. Cheung, as well as Pete Suttmeier, who testified earlier today, and Andrew Ross from the University of New Mexico, has played an important role in shaping my thinking about Chinese military innovation, and it is playing an important role in shaping scholarship and the next generation of scholars and policymakers. In my view, the Minerva Initiative deserves the full support of Congress.

Military innovation has historically been a source of both operational advantage and strategic surprise. In the mid-nineteenth century, Prussia's mastery of the railroad, rifle, and telegraph allowed it to defeat Denmark, Austria, and France and unify Germany under its control. At the beginning of World War II, Nazi Germany's development of armored warfare and tactical aviation delivered a string of unexpected lightning victories against Poland, Norway, Denmark, Belgium, Luxembourg, the Netherlands, and – most dramatically – France. Imperial Japan's use of carrier aviation, naval surface warfare tactics, and amphibious landings allowed it not only to cripple the U.S. fleet at Pearl Harbor, but also to seize American, British, and Dutch possessions in Asia in the span of five months. During the 1973 Arab-Israeli War, Egypt's innovative use of surface-to-air missiles and anti-tank guided munitions inflicted on Israel its worst battlefield defeat. The use of stealth and precision-guided munitions by the United States in the 1991 Gulf War yielded a rapid victory that shocked both participant and observer alike.

It is important to understand the scope and pace of Chinese developments. There is, on the one hand, the danger of overestimating the extent of Chinese military modernization, of crediting China with capabilities that it does not possess. Overestimation would threaten to increase the pressure for competitive arms dynamics in the region. There is also, however, the danger of underestimating Chinese military modernization. Doing so would open up the United States and other regional actors to surprise in the event of a future crisis or conflict.

China's military modernization has received increasing attention in recent years. Its January 2007 test of a direct-ascent anti-satellite (ASAT) weapon, its fielding of an anti-ship ballistic missile (ASBM), and its development of the stealthy J-20 fighter aircraft have garnered international attention.

It is increasingly apparent that the United States has underestimated the scope and pace of Chinese military modernization. Then Secretary of Defense Robert Gates admitted as much in January 2011 after the appearance of the J-20.[1] Gates' remarks mirrored those of Vice Admiral Jack Dorsett, at the time the U.S. Navy's senior intelligence officer, who has stated that the Defense Department "certainly would not have expected [the Chinese] to be as far along as they are today" in technology and has

[1] John Pomfret, 'Defense Secretary Gates: U.S. Underestimated Parts of China's Military Buildup," *Washington Post*, January 9, 2011, at http://www.washingtonpost.com/wp-dyn/content/article/2011/01/09/AR2011010901068.html.

argued that the Pentagon needs to refine its intelligence on military matters in China.[2] For his part, the then Commander of U.S. Pacific Command (USPACOM), Admiral Robert F. Willard, told reporters in October 2009, "In the past decade or so, China has exceeded most of our intelligence estimates of their military capability and capacity, every year…They've grown at an unprecedented rate in those capabilities. And, they've developed some asymmetric capabilities that are concerning to the region, some anti-access capabilities and so on."[3]

Innovation is a diverse phenomenon (see Figure 1). It ranges from imitating existing systems as well as the invention of new capabilities. It includes the development of new technology, but also new processes and organizations. And the innovations themselves can be relatively simple, or they can be complex.

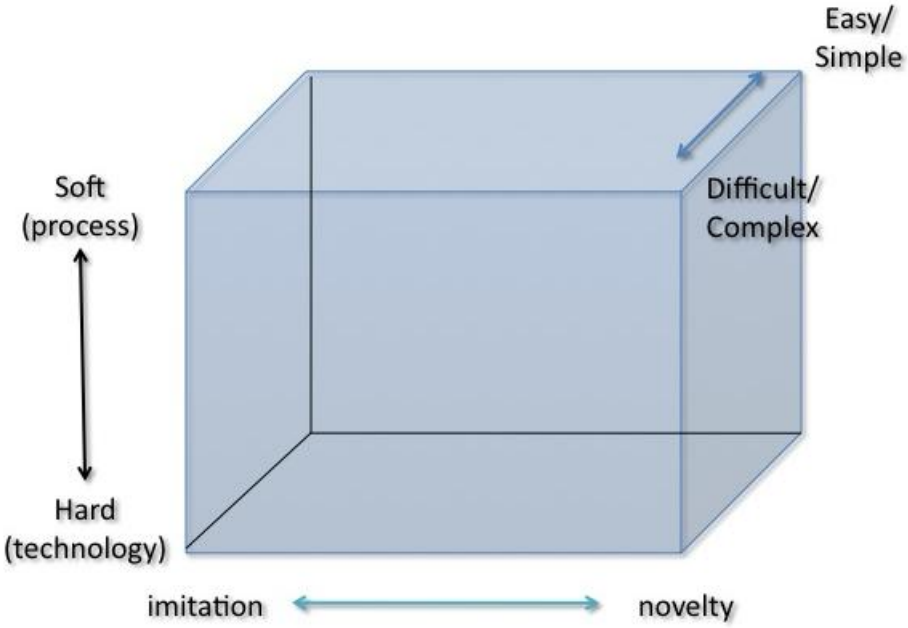


Figure 1. Classifying Innovations

To date, China's military innovation programs have been more technologically than doctrinally or organizationally focused. Doctrinal and organizational changes appear to lag behind technological advances. This is hardly surprising, however; the development of new capabilities frequently precedes the emergence of new ways of war. It is not clear that the quality of soft capability inputs match the quality and quantity of hard capability inputs.

Similarly, Tai Ming Cheung has provided a useful taxonomy for thinking about innovations:[4]

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[2] Anna Mulrine, "We Underestimated China, U.S. Official says after reports of J-20 Stealth Fighter," *Christian Science Monitor*, January 6, 2011.
[3] http://www.voanews.com/english/2009-10-21-voa8.cfm.
[4] Tai Ming Cheung, 'The Chinese Defense Economy's Long March from Imitation to Innovation', *The Journal of Strategic Studies* 34/3 (June 2011). See also Tai Ming Cheung, 'Dragon on the Horizon: China's Defense Industrial Renaissance,' *Journal of Strategic Studies* 32/1 (Feb. 2009), 29-66.

- Duplicative Imitation: Products, usually obtained from foreign sources, are closely copied with little or no technological improvements. This is the starting point of industrial and technological development for latecomers such as China.
- Creative Imitation: This represents a more sophisticated form of imitation that generates imitative products with new performance features.
- Creative Adaptation: Products are inspired by existing foreign-derived technologies but differ from them significantly.
- Incremental Innovation: This is the limited updating of existing indigenously developed systems and processes. This innovation is often the result of organizational and management inputs aimed at producing different versions of products tailored to different markets and users, rather than significant technological improvements through original research and development (R&D).
- Architectural Innovation: This refers to innovations that change the way in which the components of a product are linked together, while leaving the core design concepts untouched.
- Component Innovation: This involves the development of new component technology that can be installed into existing system architecture. It emphasizes hard innovation capabilities such as advanced R&D facilities, a cadre of experienced scientists and engineers, and large-scale investment outlays.
- Radical Innovation: This requires major breakthroughs in both new component technology and architecture and only countries with broad-based, world-class R&D capabilities and personnel along with deep financial resources and a willingness to take risk can engage in this activity.

Much of Chinese military modernization involves a mixture of incremental innovation, creative innovation, and creative adaptation. The PLA is, for example, fielding a new generation of armored fighting vehicles to replace those that are becoming obsolescent. It is also deploying more capable fixed-wing aircraft.

Of greater concern is Beijing's development of qualitatively new capabilities, particularly so-called anti-access and area denial capabilities. As the Defense Department's 2010 *Quadrennial Defense Review* put it, "Anti-access strategies seek to deny outside countries the ability to project power into a region, thereby allowing aggression or other destabilizing actions to be conducted by the anti-access power. Without dominant U.S. capabilities to project power, the integrity of U.S. alliances and security partnerships could be called into question, reducing U.S. security and influence and increasing the possibility of conflict."[5] China's progress on areas as diverse as anti-ship ballistic missiles, information warfare, and anti-satellite weaponry evidence concerted effort in areas that could yield disruptive innovation.

It is worth noting that new ways of war do not spring forth overnight. Most major military innovations came about due to the recognition of a pressing strategic or operational problem that cannot be handled through improvements to the existing force, but rather requires a new approach. Moreover, past cases of military innovation show that military services tend to develop new approaches to combat in three distinct but often overlapping phases (see Table 1): speculation, experimentation, and implementation. Each phase yields indicators that can give us an estimation of the pace and scope of innovation.

[5] *Quadrennial Defense Review Report* (Washington, D.C.: DOD, February 2010), 31.

Phase	Potential Indicators of Innovation
I. Speculation	• Publication of concept papers, books, journal articles, speeches, and studies regarding new combat methods. • Formation of groups to study the lessons of recent wars. • Establishment of intelligence collection requirements focused upon foreign innovation activities.
II. Experimentation	• Existence of an organization charged with innovation and experimentation. • Establishment of experimental organizations and testing grounds. • Field training exercises to explore new warfare concepts. • War gaming by war colleges, the defense industry, and think tanks regarding new warfare areas.
III. Implementation	• Establishment of new units to exploit, counter innovative mission areas. • Revision of doctrine to include new missions. • Establishment of new branches, career paths. • Changes in the curriculum of professional military education institutions. • Field training exercises to practice, refine concepts.

Table 1: Potential Indicators of Innovation

In the case of China, the need to coerce, or if necessary defeat, Taiwan to ensure its unification with the mainland serves as a powerful driver of Chinese military capabilities. Key to success in such a scenario would be ensuring that the United States was unwilling or unable to project its maritime and air power in support of Taiwan. One would thus expect China to seek innovative approaches to achieve that aim.

China has for some time been acquiring the means necessary to pursue unification with Taiwan. As part of its planning for a Taiwan contingency, China is emphasizing measures to deter or counter U.S. intervention in a future cross-Strait crisis. These include the ability to interdict or attack, at long ranges, air and maritime forces that might deploy or operate in the Western Pacific. It is seeking to build the capability to hold at risk regional bases and aircraft carriers. It has also developed a variety of weapons and jammers to degrade or deny an adversary's ability to use space-based platforms.[6]

Some of these capabilities represent evolutionary improvements to existing capabilities. China is, for example, fielding growing numbers of fourth-generation fighters and is developing fifth-generation aircraft. It is also deploying more sophisticated surface-to-air missiles. At sea, China is modernizing its surface navy and submarine force.[7] It is also fielding innovative systems as part of its anti-access strategy, including precision-guided conventional ballistic missiles and ASBMs. These capabilities are likely to be the most consequential for U.S. national security.

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[6] *Annual Report to Congress: Military Power of the People's Republic of China* (Washington, D.C.: Department of Defense, 2008), 21-23.
[7] *Ibid.*, 22-23.

Let me conclude with a few recommendations as to how the United States can improve its ability to detect and recognize Chinese innovation. One way to do so would be to make a systematic effort to analyze open sources such as military newspapers, professional journals, and books, as well as semi-open sources such as doctrinal publications, to improve our knowledge of foreign doctrinal debates. In many cases, they may offer the first indication that a foreign service is studying new warfare areas. The limited efforts cited in this paper demonstrate the value of the approach. It would be worthwhile, for example, to translate into English and publish key Chinese doctrinal handbooks, such as *Science of Campaigns* and *Science of Second Artillery Campaigns*. Such an effort would give the non-Mandarin-speaking expert community needed insight into Chinese thinking on defense matters.[8]

A complementary approach would be to establish multi-disciplinary research centers to examine Chinese military affairs. During the Cold War, for example, a number of think tanks studied Soviet military concepts and doctrine. As noted above, the SITC is doing outstanding work. But that program grew out of a single grant out of 24 that have been awarded to date as part of the Minerva Research Initiative, and last year Congress cut funding for the program. Much more needs to be done.

An effort to identify and track innovators may further illuminate the scope, pace, and emphasis of foreign efforts. During the 1930s, for example, U.S. attachés in Germany followed Guderian's writings, mining them for clues to German armored doctrine. A dedicated effort to identify and track foreign individuals and institutions associated with innovation efforts could prove similarly useful. How do they portray future conflicts? Who, if anyone, within their armed forces pays attention to their ideas? Are their ideas used in war games and exercises? Are they incorporated in doctrine?

Finally, some states considering innovative approaches to warfare may move beyond speculation to begin experimenting with new operational concepts and organizations. An examination of foreign exercises may offer important clues regarding new technology and doctrine. Attempts to explore innovative weapons and concepts should, for example, lead to a change in the observable pattern of exercises. An in-depth study of foreign exercise activity may reveal attempts to develop new approaches to combat.

The growth of Chinese military power has ramifications that go beyond the Asia-Pacific region. Similarly, the topic of Chinese military studies is far greater than the Asia specialist community. Rather, what is needed is a truly multidisciplinary approach – one that draws on the unique strengths not only of regional specialists, but also students of strategy, history, geography, culture, economics and technology.

[8] To date, the only such document to appear in English is Peng Guangqian and Yao Youzhi, eds., *The Science of Military Strategy* (Beijing: Military Science Publishing House 2005).

CHAIRMAN SHEA: Professor Walsh.

STATEMENT OF KATHLEEN WALSH
ASSOCIATE PROFESSOR OF NATIONAL SECURITY AFFAIRS
U.S. NAVAL WAR COLLEGE

MS. WALSH: Thank you very much. I'd like to thank the Commissioners, Commission Co-Chairs, for inviting me back.

Once again, I'm very honored to be here and have the opportunity to speak to you again. As Tom mentioned, my testimony is largely based upon a study group that I chaired last year looking at-- our task was specific--looking to see if China had a concept for a defense innovation system. And I should say I had a co-author/co-researcher, Ed Francis, who helped with that study group.

What we found was, yes, indeed, China does have a concept for a defense innovation system, and one that I believe is quite complex, sophisticated and integrated with other aspects that you've heard this morning, about China's national innovation system and other efforts to develop regional and other innovative ecosystems around the country, including what we just heard about the cloud computing and so on.

So we did find it. Interestingly enough, when I went looking for this concept and this term of art, I did not find it in the defense research or the military research, but only by finally--thinking I'm going to fail in the study group-- going to the commercial side again, looking at the scientists and how they conceive of defense innovation systems.

So when I describe this concept, it's very much in the conceptual stage and about the scientists and the officials and those who are doing strategy and policy. So what I'm going to describe is not necessarily all happening yet. It's in process. It's not necessarily all working well, but clearly the ideas, the concept, is laid out and evolving.

So what is a defense innovation system? It is very much like the national innovation system where you try to have a regional cluster, geographic cluster of smart folks from industry and universities and research, government researchers and so on, sort of put them in a place together so they can be entrepreneurial and innovative, and, of course, on the defense side--this is defense specific--China's model is very deliberately aimed at being dual use, and so my testimony goes into a lot of detail about how they plan this.

The bottom line is basically they're developing this defense innovation ecosystem on top of what is already existing, has already been experimented upon, has already to some extent been working from the early 1990s when China set up special economic zones, economic trade development zones, high technology development zones, S&T, science and technology parks, incubation centers. So all of these regional clusters on the commercial side with all these experimental services and capabilities are in one geographic area. They're now trying to do very much the same thing on the defense industrial side, and this is what's new.

And so in my testimony, I call it the system of innovation systems because they're layered--right--so there's the national innovation system, the defense innovation system being a piece of that, that dual use aspect; regional innovation systems, those clusters around Beijing and Shanghai and Guangzhou and now Chongqing-Chengdu area, and others that they're developing; and also a knowledge

innovation system where they're connecting by information communications technologies, libraries and databases, all these regional nodes, all these clusters, and again across a civil-military divide.

So this is the clear effort now on the defense side to develop this ecosystem for dual-use defense industrial development. So this is something really quite new.

What does it mean for China and for the U.S. national security and policymaking? I echo what Tom said, when I see this approach being taken by China. What it suggests to me is that the idea of leapfrogging technologically still exists, of course, in Chinese strategy and planning, but I think it's going to be more in select areas.

This seems to me a much more fundamental approach to developing a system of innovation, sort of that long-term sort of more patient strategic approach to developing more fundamental capabilities from the bottom up and innovative actors working across those stovepipes that you heard mentioned earlier today. This is the focus, one of the main focuses of China's government policies today, putting in place these actors and institutions and dynamics to allow/foster this innovation.

If so, it suggests probably the likelihood of incremental and product innovation more than, at least in the short-term, more than the radical or process innovation, and yet it sets that up for the long-term as well. So I think that both are possible. Right now, I think that the more incremental approach is more likely.

It's also a risky approach, I think, because all these systems, of course, are very interdependent so if one fails, the others could fail, and the defense side being probably the weakest of all of these in this overarching system.

I should say too the global innovation system is a deliberate part of China's strategy and plans at every level--right--so the commercial side has the global element involved, foreign investors, foreign R&D inputs and so on, and this is also going to be mirrored on the defense side, that even foreign invested enterprises will have a role to play in the defense innovation ecosystems that they're setting up. So, again, this is a multi-layered approach.

So it's risky in the sense that there's a weak link potential, but at the same time since these are ecosystems, there is also the potential that they can support each other so if the defense side is the weak link, the idea certainly is to try and bolster the defense side with these other systems and their strengths.

One last point. Being involved in a recent NRC study and some other studies that have come out by the Royal Society, looking at different countries' science and technology innovation strategies and plans, it seems a clear trend is apparent than in a global system, it's important to have both a top-down strategic guidance, a strategy in place that incorporates global innovation, globalization, and to allow that flexibility and develop those ecosystems in your nation state, as well as having that organic bottom-up innovative entrepreneurial dynamic, which is very hard to mandate, to sort of put the right ingredients in place.

I see China doing both of these now, and the latter being the main focus, in particular, for the defense side, and I see this as something quite new and could lead to some success on the Chinese part.

China is a player now in global science and technology. I put in my testimony some ideas potentially for U.S. policy, but it seems to me that science itself

is becoming globalized much like industry did, flattened, outsourced, offshored, commoditized, very horizontal, both in the commercial and defense sector. Then R&D became globalized. We have R&D investments in China and other parts of the developing world. It seems to me science is following the same trend, becoming flat, will become commoditized, outsourced, offshored.

If that's the case, and China is a key player in that, I think that this is a new world and one in which we need to perhaps ourselves have a new strategy that incorporates global innovation, national innovation, our own strategy to leverage China as a new player in this domain.

So with that, I look forward to your questions. Thank you.

PREPARED STATEMENT OF KATHLEEN WALSH
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TESTIMONY BEFORE THE US-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION

Hearing on "Assessing China's Efforts to Become 'An Innovation Society': A Progress Report"

Panel V: Defense Sector Innovation

May 10, 2012

by

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Before I turn to my remarks, let me first thank the US-China Commission and today's Co-Chairs for kindly inviting me back to provide some potential insights on the important issue of China's defense innovation. The bulk of my testimony pulls from findings gleaned through a Study Group I chaired last year on behalf of the Study of Innovation and Technology in China (SITC) project at the Institute on Global Conflict and Cooperation (IGCC), University of California San Diego, which administers the Department of Defense's China Minerva program. This Study Group was tasked with determining the contours (if any) of China's concept of a defense innovation system (DIS).[2]

The main conclusion reached by this study is this: China does, indeed, have a sophisticated concept for and is actively working to put in place a new style of modern defense innovation system (DIS). Our study showed that China is in the process of instituting a bold, new, systemic approach to defense innovation that is part of a broad array of organizational, technological, intellectual, and cultural reforms designed to establish a complex, layered, interdependent system-of-innovation-systems (SoIS) model, of which the DIS is only one important part.

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[1] The views expressed here are the author's personal views and in no way represent views of the US Government, US Navy, US Naval War College or any other institution.

[2] Mr. Ed Francis was a co-contributor to this Study Group and co-author of the draft paper presented at the 2011 UCSD/IGCC/SITC conference and workshop. For more on the findings of this Study Group, see Kathleen A. Walsh and Ed Francis, "China's Defense Innovation System: Making the Wheels Spin," Policy Brief No. 23 (September 2011) in *New Perspectives on Assessing the Chinese Defense Economy*, Tai Ming Cheung, ed. (San Diego: IGCC, University of California San Diego 2011). A longer-form book chapter is expected to be published in late 2012/2013.

China's DIS is, in fact, nested within China's notion of a national innovation system (NIS)[3], which itself departs from the ordinary state-bounded NIS concept in that it incorporates as a core concept a global dimension (i.e., leveraging foreign investments and globally sourced know-how, industrial expertise, research and development, and scientific expertise) as well as more micro-level, sub-systems of innovation, including the DIS along with a "knowledge innovation system" (e.g., nationally and/or regionally connected information networks, databases, and scholarly collections), different industry sector innovation systems, region- and industry-specific innovation clusters, and more. This complex, layered system-of-innovation-systems approach is one that reflects lessons learned from other, more innovatively developed states (particularly the United States but also studies of the approaches taken by Canada, Australia, Norway, and perhaps others, as well as reflecting a model proposed by the Organization for Economic Cooperation and Development). China's own approach, however, appears to be a more integrated, interconnected, globally oriented, and complex model suited to China's own aims and aspirations of becoming an indigenously innovative country (see attached chart).[4]

The Chinese approach to developing this innovation-oriented system-of-systems dates back to at least the late 1990s and is outlined and explained most succinctly in a 2006 brief by a senior researcher at the National Research Center for S&T for Development (NRCSTD), which explains that China's NIS concept — in which the DIS is a key part— is designed around the following core components[5]:

- **Enterprises as the innovative center and linchpin** (with the "Defense innovation system combining military and civil use" listed as a subcomponent");
- **Government or state-sponsored research institutes** comprising a "knowledge innovation system" along with universities and colleges;
- **"S&T intermediate service system"** (e.g., investment zones, science parks, incubators, industry associations, technology transfer and product promotion centers, etc.);
- "**Regional innovation system** embodying individual features and advantages" (i.e., the Yangtze River Delta region and other geographically oriented clusters); and
- "**Government system coordinating S&T policies and economic policies**." [emphasis added][6]

Each of these core components is critical to China's efforts to develop its DIS into a more productive, efficient, and advanced source of innovation for military modernization. The first component —placing enterprises at the center of innovative activity— is an obvious first step in today's corporate-dominated global order in modernizing any innovation system, yet has proven particularly difficult in China's experience given the legacy of Soviet-era-like defense industrial development, the continued state-owned enterprise model that largely governs China's defense conglomerates, the limited degree of market-based competition between and among these conglomerates, and more. Current efforts underway to make these enterprises the innovative center of China's DIS include some opening up of the defense industrial sector to private and even foreign investors, plans to continuously reform this

[3] According to the Organization for Economic Cooperation and Development, "The national innovation systems approach stresses that the flows of technology and information among people, enterprises and institutions are key to the innovative process. Innovation and technology development are the result of a complex set of relationships among actors in the system, which includes enterprises, universities and government research institutes." OECD, *National Innovation Systems* (Paris: OECD, 1997), p. 7.

[4] Author interviews with innovation experts in China (December 2011).

[5] Min-Jeong Kim and Jai S. Mah, "China's R&D Policies and Technology-Intensive Industries," *Journal of Contemporary Asia*, vol. 39, no. 2 (May 2009), pp. 264-265.

[6] Gao Changlin, "Chinese Science and Technology Indicators System: Toward an Innovation-Based Nation[s]," presentation to the OECD-MOST Indicator Workshop in Chongqing, PRC (October 19-20, 2006). See also Ed Francis and Kathleen A. Walsh, "China's Defense Innovation System: Making the Wheels Spin," draft conference paper presented to the IGCC "Summer Training Workshop on the Relationship between National Security and Technology in China" (June 20-25, 2011) and the "Workshop on Chinese Military Innovation" (June 28-29, 2011).

sector institutionally in order to regularly shake up vested interests in the status quo that build up over time and reside in the powerful conglomerates, and efforts to make the head conglomerate of each defense industry sector be more involved in cross-industry sector activities —in what some have termed a "matrix approach" to promoting greater defense innovation— in order to foster opportunities that otherwise have and might be missed in cross-industry innovation and entrepreneurship (e.g., aviation and the automotive sector collaborations and potential cross-sector innovations).[7]

China's research institutes —whether government-run, university-based, or residing in industry— are also key to the PRC's ongoing development of a nation-wide "knowledge innovation system," a core component in China's strategy to develop a deliberately dual-use innovation model, one intended to simultaneously serve both commercial and defense industrial development goals. This is one of the key areas of weakness in China's past and present efforts to foster greater cross-disciplinary research collaboration and innovation. China's research communities tend still to be isolated from one another, geographically, institutionally, and socially, as do domestic researchers from the growing number of foreign-invested enterprise R&D workers. In order to try to overcome these persistent obstacles, China is working to develop nation-wide and regional information technology resources (networks, databases, and libraries) designed to connect key innovative hubs or technology and research clusters, institutions, and other actors, sharing research results electronically and promoting greater use of government-funded research for defense and commercial purposes. The linking up electronically and otherwise of these various centers of innovation across China is part of a broader, ongoing "grid approach" that seeks to connect the country's geographically and institutionally dispersed research communities, making each a key node in a national, inter-connected, knowledge-based, dual-use innovation system.[8]

One of the most important components in China's SoIS approach to modernizing its DIS is the third, so-called "S&T intermediate service system" (which refers to China's array of different sorts of investment zones, science parks, incubators, industry associations, technology transfer and product promotion centers, etc.). This component represents all the various experimental investment, innovation-promoting, and technology transfer efforts and services China has been attempting and perfecting over the past 20 years of reform aimed at hastening and advancing economic development, particularly in the commercial sector. This same approach is now being applied to the defense sector, with the recent emergence of defense industry- and civil-military-specific investment zones, S&T parks, technology promotion centers and related activities geared toward hastening, advancing, and socializing defense sector technologies, expertise, and innovations. In short, having found that many of these efforts have succeeded, at least in part, in the commercial sphere to prompt more innovative and entrepreneurial activity, Beijing is adopting a similar service-oriented approach now for the defense sphere. It is not clear, however, whether these sorts of S&T- and innovation-friendly services will have the same effect on the defense sector as on the commercial, which benefited from what a World Bank report termed industrial "Plug and Play" zones that allowed small and medium-sized enterprises as well as foreign investors to more readily compete in there area or regional markets and become part of developing technology clusters.[9] Whether or not China's private-sector, smaller-size enterprises can compete with or adequately supply China's large-sized defense conglomerates in a similar way remains to be seen, although it appears that some progress is being made in this regard.

The fourth component is also critical to China's efforts to establish a more modern and productive DIS. As in the commercial realm, China's strategy over the past several years has been to promote regional innovation systems

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[7] "Strive to be a Powerhouse in China's S&T Development – 2010 Annual Meeting of CAS in Beijing," *Bulletin of the Chinese Academy of Sciences*, vol. 24, no. 1 (2010), pp. 1-4.

[8] CAS Bulletin (2010).

[9] In a fascinating study comparing the success or failure rate of investment zones in China, Vietnam and Ethiopia, this study found that China's "Plug and Play" industrial and investment zones played a vital role in China's comparative success. See Vincent Palmade, Hinh T. Dinh, Vandana Chandra, "China's secret weapon in light manufacturing: Small and Medium Enterprise-oriented 'Plug and Play' industrial zones," World Bank blogs (November 29, 2010), accessed online at http://blogs.worldbank.org/developmenttalk/node/569.

(RIS), based on the industrial, geographic, technological, and other particular assets and characteristics of each particular region of China. This is an effort to prevent nearby provinces, municipalities, and local areas from competing with one another for the same domestic and foreign resources and investors (leverage that foreign investors can and have exploited in the past) as well as to pursue Beijing's top industrial, scientific, and technological objectives in a strategic, distributed fashion. So, for instance, Shanghai will dominate development of certain strategic industry sectors such as automotive, shipbuilding, and biotechnology, while other regional zones and innovation systems will concentrate on information technology, aerospace, energy or other strategic sectors prioritized by central authorities. Three new economic zones that will serve as separate regional investment zones, innovation systems and technology clusters have been approved in recent years, one in particular with important implications for the defense sector. Under the 11th Five-Year Plan, the three new regional zones are the Chengdu-Chongqing Economic Zone (CCEZ), which is important in that it includes the traditional Third Line defense enterprises and Mianyang research area; the Guanzhong-Tianshui Economic Zone or "West Triangle Economic Circle"; and the Beibu Gulf (Guangxi) Economic Zone (also referred to as the "Little Beibu Gulf" and encompassing Beihai, Qinzhou, Fangchenggang, Nanning, Changzuo, and Yulin).[10] Each focuses on certain industry and high-tech sectors but at the same time is expected to increasingly be connected to and, authorities hope, collaborating innovatively with other zones, clusters, and regional innovation systems across the country via, among other means, the information-sharing grid approach noted earlier. In this way, authorities seek to increase access of still-centrally located defense researchers, academics, enterprises, and others to the more economically and innovatively vibrant coastal areas; the latter, in turn, will have greater access to potential dual-uses of defense research taking place in central and western parts of the country.

The fifth component addresses the changing view of the role of government in China's innovation strategy. Though subtle, there has been a clear shift in thinking over the past decade in terms of what role central authorities should take when it comes to promoting innovation. Today's view is that the most productive role for government in such cases is to serve more as stated in the NIS model: as lead coordinator, providing the necessary strategic, long-term guidance to key actors and institutions, but without getting into the particularly quantitative mandates and micro-managing so often witnessed in past decades. The hope is that this more flexible approach on the part of government authorities will allow prospective innovators a freer hand as to how exactly they see fit to pursue innovative opportunities supported, guided, and prioritized by the state. Old habits are hard to break, however, particularly in a still largely centrally planned economy and politically authoritarian structure. Although the number of rules, regulations, catalogues, and other government policy documents have not lessened, the language and tenor used in promoting state aims has to some degree reflected this newer tone and approach to government as coordinator and strategic guide versus implementer of mere mandates and quotas. Only time will tell, however, whether this new approach will truly take hold, particularly at lower levels of government authority (i.e., provinces, municipalities, villages, and townships) and accepted among innovators themselves. It is important to note, however, that recent studies comparing progress across different national innovation systems find that states possessing both strong top-down strategic guidance on innovation as well as a robust, organic, bottom-up innovative dynamic fare better than those reliant on either one or the other foundation.[11] Chinese authorities today support both approaches, with a particular focus at present on spurring the bottom-up dynamic through a focus on incentivizing and enhancing civil-military, cross-disciplinary, and other cross-cutting relationships among China's innovative communities.

Taken together, these five components comprise China's basic strategy for establishing a more modern and robust DIS, as a key part of China's overarching NIS, and one that is integrated with the various other levels of innovation systems simultaneously being pursued. In this way, China's approach bears a striking resemblance to that portrayed by the OECD in a study outlining the notion of an NIS published in 1999. Yet China's concept also has interesting and distinct features, including the deliberately dual-use nature of China's model.[12] Also,

[10] Francis and Walsh (2011).
[11] Royal Society (2011); and NRC (2010).
[12] OECD, *Managing National Systems of Innovation* (Paris: OECD, 1999).

while some states' NIS might focus primarily, if not exclusively, on promoting domestic linkages, China's NIS *and* DIS both emphasize international linkages as a core element.[13] Both distinctions fit the pattern of China's past strategic development plans that, despite much Western criticism, persist in attempting to establish an "indigenous innovation" capacity, in large part by leveraging foreign technology transfers, and to spin-off as well as spin-on civil-military technological advances, despite the technological, institutional, time-consuming, and cost-factor difficulties inherent in this approach. As such, China's pursuit of a DIS as nested within its NIS appears in important ways to depart from more traditional notions of what constitutes an effective NIS and DIS but represents a new stage in China's ongoing innovation efforts.

The key reason why China's bold ambitions in this instance are worth taking seriously is the reality of an increasingly global S&T phenomenon that is taking place simultaneously. The evolution of globalization has reached a new stage. Prompted initially by cheap, fast, mobile information communications technologies and networks, the current wave of globalization rapidly took hold in the developed and developing worlds over the past two decades, concurrent with China's economic growth. In turn, this led to commercial outsourcing and then global offshoring of industrial assembly and corporate manufacturing, services and marketing. As the latter processes matured, the demand for globally located commercial R&D activities took hold and has become a globally resourced endeavor, China being a leading foreign R&D investment location among still-developing countries. The final stage in this story, it appears, is also now being told, as science itself becomes an increasingly global, competitive endeavor that is likely to lead over time to the same market-oriented, nation-based, competitive advantage dynamics that we've seen in the other stages of industrial globalization.[14] In short, scientific research and the innovations or inventions it might spawn, as well as the scientists and innovators themselves are increasingly mobile and globally dispersed –including in China, who is actively courting international scientific resources, foreign universities, fellows, and scholars to serve its dual-use innovation ambitions. The question then arises: can or will China in time become as, or an even more, appealing and/or competitive market for scientific and innovative undertakings than the United States? The question holds obviously important implications for US national security interests and for US-China relations.

Implications for US National Security and Policy

Given China's ambitious innovation aims and activities, including in the defense realm, the United States can decide among a number of options. The temptation, of course, will be to try hold back China's innovative capacity via denial of US and, to a likely increasingly ineffective extent in such a globalized age, allied inputs. Yet given the scope and scale of China's increasingly worldwide reach and its fast-expanding scientific, technological, industrial, and scholarly ties across the globe, this seems a flawed approach that is more likely to produce diminishing returns over time than strategic gains, since any hope of containing China's access to non-military scientific, technological, industrial or otherwise intellectual knowledge is an increasingly fool's errand in today's globalizing environment and could do more to isolate the United States from global S&T dynamics than to undermine China at this stage. As such, the risk in doing so now arguably outweighs that of engaging strategically, if selectively, with China on such matters. Another option, often the default, is to do nothing. This,

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[13] The original notion of an NIS as depicted by Freeman did presume national boundaries, although this has since been the subject of much debate. See Chris Freeman, *Technology Policy and Economic Performance: Lessons from Japan* (London: Pinter, 1987); and Judith Reppy, "Competing Institutional Paradigms: Conceptualizing the Role of Defense Industries in National Systems of Innovation," in Judith Reppy (ed.), The Place of Defense Industry in National Systems of Innovation (NY: Cornell University Press, 2000), p. 1. Others have termed China's approach more of a "Global Innovation System," suggesting China abandoned the borders-limited NIS model in the early 1980s. See Jon Sigurdson, "Regional Innovation Systems (RID) in China," Working Paper 195 (July 2004), p. 5, accessed online at http://swopec.hhs.se/eijswp/papers/eijswp0195.pdf.

[14] See Royal Society, *Knowledge, Networks and Nations: Global Scientific Collaboration in the 21st Century* (London: The Royal Society, 2011); and Committee on Global Science and Technology Strategies and their Effect on US National Security, *S&T Strategies of Six Countries: Implications for the United States* (Washington, DC: National Academies Press, 2010).

too, would be unwise, as it risks US innovators falling behind growing international S&T competition. What, then, to do? The practical, if not optimal, answer from a US national security perspective would be to find ways to better leverage China's (and other developing states') growing openness, support of, and access to the world's scientific, technological, industrial, and otherwise intellectual assets. This can only be achieved, however, via engaging with China and others on matters of S&T, something the United States has long done well and from which our national security enterprise has prospered tremendously over the past half century. Along these lines, it is heartening to see that the Defense Science Board has begun to think in part about this issue, as suggested in the January 2012 report by the Task Force on Basic Research in a global S&T age.[15] But much more strategic thinking is needed on this topic of what the United States' S&T development and innovation strategy and policy will be in a world of globalizing S&T where China is an increasingly central player if we hope to stay ahead of China's innovative ambitions in the defense realm and otherwise.

As outlined in a recent study by the United Kingdom's Royal Society, today researchers and scientists increasingly collaborate across international boundaries and on projects that involve individual, non-state, state, and multi-state scientific cooperation, essentially working on scientific and technological challenges wherever they find the best talent, infrastructure, and institutional or government support. As a result, every step on the innovative ladder —from concept development and basic scientific research through applied R&D to technology development and marketing and other innovations— has been to a growing degree outsourced, offshored, or is increasingly available through international collaboration, with the important exception of select secret defense and weapons research. This new paradigm is one that China and others seek to exploit in pursuit of their own national and defense innovation systems; it is one the United States must continue to pursue strategically, including with regard to China.

Conclusion:

China's bold approach to developing a vibrant, 21st century DIS is by design dependent upon the success (or failure) of the other systems-of-innovation-systems that make up its complex, layered design. For China, this could prove to be a disastrously ambitious endeavor. Yet, given the nature of innovation, which appears to thrive on just the sort of laissez-faire, interconnected, cross-cutting, interdisciplinary, and entrepreneurial *ecosystems* that China is seeking to put in place across the country and has had a degree of success in doing for the commercial sector, these efforts hold the potential to prompt much more innovative results from Chinese industry, including from the defense sector in the years to come. China's present approach to fostering defense and related innovation suggests a new degree of strategic patience, indicating that Beijing feels time is on its side, allowing China to take a more fundamental, bottom-up approach to devising a more effectively innovative system-of-innovation-systems model (rather than rushing to leap-frog technology advances when- and wherever possible, although this approach is likely to persist in certain high-priority areas). If so, this would portend for the short-term a greater likelihood of incremental and product innovations, particularly where it serves to fill critical capability gaps in China's commercial and defense sectors. Perhaps this accounts for some of the more recent advances coming out of China's defense sector, such as the new classes of submarines, ships, and missiles, the J20 stealth fighter prototype, and other recently unveiled defense technologies and capabilities. According to Pentagon experts, "Defense industry modernization accelerated in the mid-1990s based on reforms to rationalize military procurement and increase innovation among China's state-owned defense companies. These reforms have enabled the development and production of select weapon systems, such as missiles, fighter jets, and warships, approaching performance parameters comparable to Western systems."[16] Over the longer-term, if this more fundamental approach to innovation continues and effectively takes hold (notably, two big "ifs"), it could signal a new ability by China over time to innovate in more advanced ways, both in terms of process innovation

[15] Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, *Report of the Defense Science Board Task Force on Basic Research* (Washington, DC: US Department of Defense, 2012), online at www.acq.osd.mil/dsb/reports/BasicResearch.pdf.

[16] See US Department of Defense, *China Military Power* (2007), pp. 26-27 online at http://www.defense.gov/pubs/pdfs/070523-china-military-power-final.pdf; and Francis and Walsh (2011).

and possibly even more radical forms of innovation.

For the United States, the question remains: what are we going to do vis-à-vis China's efforts today to establish this bold SoIS model to ensure that the US defense sector, in particular, is even more innovative in a global science, technology and industrial age, both in the near and long term? If ignoring or in some limited way containing China's S&T and innovative reach are not viable strategic options, then what *is* an appropriate strategy? There are no simple answers to this complex question. But it is imperative that this question be tackled, and a US innovation strategy for a globalized S&T environment in which China plays an increasingly important role in the 21 century be articulated.

PANEL IV: QUESTION & ANSWER

CHAIRMAN SHEA: Thank you very much.

I'll take the first question. Dr. Mahnken, you say that it is increasingly apparent that the United States has underestimated the scope and pace of China's military modernization. I don't know if you're familiar--we issued a staff report that looked at four separate weapon systems that essentially made, reached that same conclusion.

I was wondering why do you think we underestimated China's military modernization, have any lessons been learned,and are we taking appropriation action to ensure that we keep abreast of developments in China?

DR. MAHNKEN: Obviously, any comments that I would be making on this are just based on unclassified statements.

CHAIRMAN SHEA: Sure. So is that report.

DR. MAHNKEN: Yeah. And to truly understand the state of our knowledge in the U.S. intelligence community, you'd have to conduct a classified assessment. But certainly in my prepared testimony, I offer quotes from Secretary Gates and from current and former senior leaders to that effect.

Look, I think it is true. I also think it is in some ways to be expected. I think historically there's a tendency to underestimate the capabilities of rising powers. And I've actually done historical research looking at U.S. assessments in the 1920s and '30s of Japanese military capability, and I think you see a similar pattern to what we have seen in recent years with our assessments of Chinese military capability.

We underestimate because in trying to look to the future, we can't help but look back to the past. We judge as we try to look forward, we do so with reference to past performance, and truth is rising powers, you know, modernizing militaries tend to, tend to get better. Look, the Chinese military in the 1970s, 1980s, '90s, was not a first-rate military, and I think that image of all the limitations of the Chinese military, its dependence on outside technology, its dependence on outside arms purchases and so forth, cannot help but color our views of the future, although I think those views have tended to lag behind the reality.

So you have things like the 2007 ASAT test that was, at least to some, sort of a wake-up call. The development of the DF-21D and the revelation of the J20, again, I think, you know, some future historian will do a good reconstruction of the life cycle of those programs and perhaps see them as less surprising.

But they appear as surprises because they go against our preconceptions, and my concern is that there still is a fairly wide held preconception of a China that is not as capable as it is. Maybe that preconception is less prevalent in government than out of government, but I still think it does affect things, and I think we do set ourselves up for a future surprise in holding that view.

Now, that having been said, you don't want to overcompensate and overestimate, but I think, you know, if we look at kind of the recent track record, it has been one of underestimation.

CHAIRMAN SHEA: Okay.

DR. MAHNKEN: It's been in part because of the phenomenon that I just mentioned, also because of Chinese opacity because what we, you know, we learn about weapons when they're tested, when they're unveiled. We don't see them kind of as

they're coming along. Their secrecy and deception, I think, definitely has played a part.

CHAIRMAN SHEA: Okay. Speaking of potential surprises, the 2006 Medium and Long-Term Plan lists 16 priority technology development projects, and three of them are unnamed classified military projects.

There's been some speculation on blogs about what they are. Do you have any--Ms. Walsh or Doctor--any ideas or speculation about what those projects might be?

DR. MAHNKEN: I do not. I mean I've, certainly, I've spoken to others who have ideas as to what they might be. You know, my colleague Tai Ming Cheung from UC-San Diego has done some educated guesswork there.

CHAIRMAN SHEA: Yeah. He lists three.

DR. MAHNKEN: Uh?

CHAIRMAN SHEA: He says--

DR. MAHNKEN: Yes.

CHAIRMAN SHEA: --they're inertial- confinement fusion laser projects, second-generation Baidu satellite navigation system--

DR. MAHNKEN: Right.

CHAIRMAN SHEA: --and a hypersonic vehicle technology project, which I just sort of read about in the open sources.

DR. MAHNKEN: Right.

CHAIRMAN SHEA: A space plan, I assume what that is.

DR. MAHNKEN: Right, right. But that is speculation.

CHAIRMAN SHEA: Right.

DR. MAHNKEN: Yeah, absolutely.

CHAIRMAN SHEA: Thank you.

Commissioner Wessel.

COMMISSIONER WESSEL: Thank you both for being here; Professor Walsh, for your return.

I'd like to grab from the past panels we've done today, which has primarily been, as you know, in the technology and the economic component issues and connect that, if we can, to what you're talking about here.

And our last panel, as you know, was on cloud computing and supercomputing. Chinese doctrinal writing talks about asymmetric warfare and the need to utilize cyber assets potentially to even the game up. We've had a massive expansion of Chinese capabilities in this area, and certainly some world-class players--Huawei, ZTE and others-- that are coming to the world stage.

How do you view the use of these technologies, which, I don't want to say they're leapfrog, but they really are cutting edge? They are not, you know, several generations behind the U.S., but they're catching up, and actually Huawei with, I guess, 4G has been getting great marks around the world.

How do you view that scientific development, which many claim are being done for economic reasons, how do you view them as integrated, if they are, into any defensive posture?

MS. WALSH: Let me take a stab at that, and if I'm going astray, you let me know.

COMMISSIONER WESSEL: You mean if I don't like your answer?

[Laughter.]

MS. WALSH: Well, hang on one moment. Looking at Huawei and some of these other companies in early stages, back, you know, almost ten years now, visiting them and asking them, well, how are you developing your commercial capabilities and they, of course, want to be innovative and competitive with foreign companies, and so I talk to them, and then I talk to foreign partners that they were required to have, joint ventures requirement.

COMMISSIONER WESSEL: Right.

MS. WALSH: And so talking to the foreign partners, it was, while there were only two or three Chinese partners we have to choose from, so, you know, a limited set, talking to the Chinese side, well, we can deal with anyone. We can have multiple partners across and up and down the supply chain, everything from eventually research to marketing to assembly to manufacturing, and they do this, and they have all these partnerships entirely across the industrial chain, and to learn all aspects of it with all these different foreign partners, some of the best in the world.

COMMISSIONER WESSEL: Right.

MS. WALSH: So that model that I think was very clearly the case then is, I think, now the idea at least is to apply that to the defense side, to have more foreign-invested companies deal at the lower level, supply level and so on, partner with some of China's defense firms. Of course, they have very long supply chains as well, the ten defense conglomerates, but they oversee their industry sector.

So I think they're trying to apply a similar model in order to gain this understanding of the entire industrial supply and R&D, you know, the entire chain of production. That seems to be what they're hoping to do. They've had some problems because when they first opened up foreign investment a year or later, they closed some of it back up, and they have their own security concerns, of course, in this endeavor, but it seems to me they're trying to apply a similar approach because it's worked pretty well for at least these select companies.

COMMISSIONER WESSEL: But if you're going to look at--and I appreciate that--thank you--if you're looking at an asset analysis, clearly our forces are massive, our training is great, China is several steps behind if one looks at major platforms, air, sea, land. Cyber is an area that is untested.

How do you view the maturation or the evolution of Chinese assets in that realm and the focus, if there is a focus, for them in trying to either leapfrog or just become world-class to ensure that they have the assets needed, again, in that asymmetric approach?

DR. MAHNKEN: I would think about that in two dimensions. I mean one is, you know, information technology is so central to U.S. military effectiveness and has been so central. The Chinese recognize that, and they write about integrated network enabled warfare, sort of their view of what modern warfare is all about.

So I think part of what they're doing is building up an information capability to support their own military capabilities. They also secondarily, or secondly, not necessarily secondarily, you know, they see vulnerabilities that our reliance on information technology has created in our force, force posture.

So to the extent that IT is the new sort of coin of the realm, I think they see it both supporting their own capabilities but also as a countermeasure to some of our capabilities.

COMMISSIONER WESSEL: Anything else, Dr. Walsh?

MS. WALSH: I would just add that I think, at least I heard the answer or an answer to that in the previous testimony, that this idea that they're setting out this innovative ecosystem, this Chongqing center, bringing, you know, the actors and institutions in one place to try and both develop their own capabilities but also--or asymmetric capabilities--and dealing with different partners, including, I imagine, foreign partners, at least to some extent. It's something I haven't researched. I'm not a cyber expert.

But it seems to me that this is a bold and fundamental approach that could lead to these new or novel types of approaches, again, for dual-use purposes.

COMMISSIONER WESSEL: All right. Thank you.

CHAIRMAN SHEA: Commissioner Bartholomew.

COMMISSIONER BARTHOLOMEW: Thanks very much and thanks to both of our witnesses both for your testimony today and for the public service that you have put in and that you continue to do. I think we all benefit from it.

I want to get this issue--I'm struggling a little bit about dual-use. How you get a handle on dual use in contexts like this, particularly if we're talking about ecosystems?

Scientists can frequently be stovepiped. You know they live in their own section of the world, and how does one get a handle on scientific knowledge sharing, so that when we have these scientific exchanges, people might be inadvertently giving information that in the context in which they're looking at it, it's fine, but in the context of an ecosystem, it might be turning something over that is key to something that maybe is a problem for our national security?

MS. WALSH: Okay. If you look at it from the U.S. point of view, there are risks, of course. China's point of view, at least looking at defense innovation, this has been the problem.

As you've heard earlier, these stovepipe communities, particularly on defense side of research, government researchers largely in the central western area apart from the dynamic vibrant economy on the coastal areas, the university academics who are, you know, in their own areas doing their own research, and then industry. So all of these actors and other sectors are very separate from each other. And that has been a real obstacle for defense innovation.

So I think the Chinese, would see it from the opposite point of view, that they need more togetherness, and they're putting in place, you know, civil-military integration development zones, science and technology parks, that are defense and dual-use oriented services to get them to work together.

Associations asyou heard earlier, get these people to know and network together and communicate electronically, so I think that at least from China's point of view, they see the problem in an entirely opposite way.

COMMISSIONER BARTHOLOMEW: Right. But what are they learning from us? I mean that, I guess, is the dual-use piece of it that I worry about, which is that we have a number of cutting-edge American companies working, for example, in computing who are doing work in China or there are scientific conferences that take place where there are interactions between people, and how do we try to make sure that our brainpower and knowledge is not being used in a way that fits into something that China is doing that could become a national security threat to us?

MS. WALSH: I actually look at it now in a different way. I think there is a

tipping point because of the globalization, as I tried to describe, of industry R&D and now science and technology because of that, and it would be different if it weren't that way.

I think we lose more if we don't engage. Because China is becoming a player in global science and technology, because they're becoming a location for advanced science and technology, as well as R&D in industry, if we're not engaging with them, as we heard, you know, somebody was bragging at a Chinese conference, they're attracting conferences, worldwide conferences with worldwide experts not only in science but industry. Every industry is having an association or annual conference in China.

They have the drawing power that we have as well, and I think if we're not engaging with them, we're going to miss important innovations and we'll be continually surprised. So I think we might have hit a tipping point asthose risks that you described still remain. Absolutely. But I think now the greater risk is of us not being there to have the listening post, to have the people there to understand what the Chinese and other people working in China are doing. I think that right now is the greater risk.

COMMISSIONER BARTHOLOMEW: Dr. Mahnken.

DR. MAHNKEN: Yeah. I think, yeah, look, I think it is a--what you laid out is a tremendous challenge in that we certainly want to reap the rewards of engagement with China, including in the fields of research and development, but by the same token, we also have to safeguard both economic and then also military knowledge.

How we do know what that inflection point is, what that balance point is? Kate and I might disagree on that, but I think trying to figure out what that point exactly is, is a genuine challenge.

COMMISSIONER BARTHOLOMEW: Are people out there trying to figure out what that point is, or is this by the time somebody wakes up and says, well, this is a problem, we've lost it all already?

MS. WALSH: That's one of the reasons I've tried to advocate that we need a strategy to deal with just these types of issues.

DR. MAHNKEN: Yeah, no, I mean I think that's right. I think there is recognition of the challenge, but I don't know that anybody has come up with any brilliant answers. Otherwise, we would have given them to you.

COMMISSIONER BARTHOLOMEW: Yeah. It's just, for those of us who have been following these issues for 20 years or so, there have been concerns about exchanges all along the way. Some of us continue to have some concerns on mil-to-mil exchanges that they learn far more than we do.

So, Ms. Walsh, I go into that with a little bit of skepticism. What are our scientists actually learning at those meetings? Are they learning more than the Chinese are learning in exchange from our people? And for some people who are pure scientists, the knowledge is what matters, not who has the knowledge and what they do with it, which I think is a real struggle, too.

MS. WALSH: I just think that there are likely ways that we could leverage this, and that I think it's in our national interests to exploit this. It is happening. You describe the nature of science well, and I think rather--in addition to finding a balance to constrain it, I think we should find also a way to leverage it that I don't think we're doing today.

DR. MAHNKEN: Yeah, I think there's certain--I grew up around scientists. I

grew up around oceanographers, and there is this view of just that sharing knowledge is an absolute good and is a positive ethic.

In some ways I worry less about business because there the culture is one of competition, healthy competition, and you want to safeguard your competitive edge.

And so I just think it's a challenge that we're going to continue, we're going to continue to face, and I wish I had some brilliant insight and a quick answer to it.

COMMISSIONER BARTHOLOMEW: Well, you actually raise then another interesting issue, which is, you know, we've talked a little bit about the difference in the cultures, our academic cultures. For our scientists, yes, sharing knowledge is part of our scientific culture. Is that true for Chinese scientists also? I just really don't know?

MS. WALSH: I'm no expert, but I think so. My impression has been that China, and particularly younger generations, have a new faith in science and technology to answer a lot of their problems, and I think the scientific ethic is taking or has taken hold in the large part of China.

The fact that they're still largely segregated, I think, diminishes this, but they're promoting this. So I'd expect to see more over time for both those organic reasons as well as those policy implications.

DR. MAHNKEN: I would say, though, that I think there are some significant cultural differences in that we certainly see it in the U.S. and the West when looking at Chinese scientific papers. So the academic community in the United States and the West has a very strong prohibition against plagiarism. It can end your career.

A lot of scientific papers coming out of China--also theses dissertations--are plagiarized. And so that I would just point out, that is a very clear cultural difference. There seems to be much more acceptance of plagiarism in China than in the West. Whether that also goes with an inability or unwillingness to share, again, I'm not familiar with any studies that have looked at just that topic. I think it's a good question.

COMMISSIONER BARTHOLOMEW: Is the plagiarism of other Chinese sources and scientists or is it West, plagiarism of Western?

DR. MAHNKEN: Well, it tends to be plagiarism--well, and this is some part of the reason why some of these figures on Chinese publications and so forth are actually inflated to a certain extent. Well, it's like plagiarism in general. You tend to plagiarize the best and the brightest. So I think the plagiarism tends to be disproportionately of Western scientific publications and less so of Chinese.

COMMISSIONER BARTHOLOMEW: Okay. Thank you.

CHAIRMAN SHEA: Commissioner Cleveland.

COMMISSIONER CLEVELAND: Is the focus of the innovation that you see on the defense front Taiwan?

DR. MAHNKEN: I would say as a general, you know, as a general principle, military organizations, like other organizations, tend to innovate most when they face a problem that they can't solve conventionally, and I think for the Chinese military, the challenge posed by the need to coerce and if necessary invade Taiwan has served as the focus of a great deal of innovation within China.

So, you know, in the early '90s, you had a situation where the PLA was unable to gain air superiority across the Taiwan Strait, and therefore was really unable

to do much to actually coerce Taiwan, could shell offshore islands and so forth, but really couldn't do much.

And so it's not surprising that in the years after that, the PLA has acquired hundreds, over a thousand short-range ballistic missiles, including precision-guided short-range ballistic missiles, has developed an anti-ship ballistic missile, ASAT.

I think a good locus of the most innovative capabilities that China has developed have been focused on solving, if you will, their Taiwan problem. Of course, these capabilities have applicabilitybeyond Taiwan. But, yeah, I think Taiwan has served as a real driver of innovation.

If you go back a generation, you know, it was the, the sense of, great sense of threat that China faced in the late '50s and early '60s that motivated their nuclear weapons program and their first-generation ballistic missile programs. So, yeah, I see a very high correlation between an operational strategic problem and innovation in the case of China.

MS. WALSH: I'd agree, at least in part. I think the Chinese are also, of course, looking at the Americans. So think the focus has been, particularly where they're leapfrogging their technologies or trying to, has been to fill some of these capability gaps and so that sort of incremental and efforts to leapfrog.

I think at this point they feel they might have time because at least the Taiwan situation has not been as critical of late, and there is more cross-trade and so on going on, so I think Taiwan is a piece of it, but I think the United States and others even, perhaps more so today.

And yet I was struck yesterday. I saw some Chinese firm developed an MRAP, mine resistant, you know, anti-personnel, or not anti-personnel, but you know, up-armored Humvee. You know why? That's not going to be for Taiwan. I don't know what that's for, but I suspect that Taiwan is a part but not the only driver.

COMMISSIONER CLEVELAND: Thank you.

In your written testimony, Dr. Mahnken, you talk about an effort to identify and track innovators. I'm going to turn on you the questions that you raise. Who do you see as the key innovators in answering the questions you pose? How do they portray future conflicts? Who if anyone within the armed forces pays attention to their ideas? And are their ideas used in war games and exercises? And how are they incorporated in doctrine? Is the STC a key player? Who, how would you answer your own questions?

DR. MAHNKEN: Well, I wish I had all the answers to the questions. That would both make me look better and also probably be more reassuring, but, look, I think, I think certainly the history of past cases of innovation, particularly major innovation, tell us that there are a number of key individuals involved, and even in the case of China, you know, we know that the Chinese missile program, that there really were, the first-generation missile program, the nuclear program, really a handful of key folks.

And that's been true in other cases as well. So I think it's worthwhile to try to peel back, you know, who are the key folks in each of these programs, and this is not tremendously sensitive information. In many cases, the information is out there. We just aren't really looking and aren't thinking in those terms.

You know, in each of the weapons manufacturers, you have key designers, key administrators. We just need to get a better handle on that. Part of this Minerva

Research Initiative grant that UC-San Diego has is working towards that, but again I think more, more can be done there, again, to get better clarity on what's actually going on at a very fine-grain level.

MS. WALSH: I'd just add maybe, at the top level, I think they are listening and they are strategizing. I think China's fundamental problem in defense innovation is at the lower level. So it's how do you get those individual actors and scientists and researchers to interact with one another and get the local regional provincial officials to buy into this approach.

I think it's not atypical for Chinese history to have the local official be the problem. And so I think that's what they're struggling with, trying to push this down through the system and have it be accepted and adopted at the local level, and I don't know how much time that will take, but it seems that's a current issue, one of the fundamental ones today.

CHAIRMAN SHEA: Commissioner Slane.

COMMISSIONER SLANE: Thank you very much for coming today.

One of the things that I worry about are the cutting-edge R&D centers that are going into China by Boeing and Intel and General Electric and the optoelectronics industry. It just seems to me that it's very difficult to establish any kind of firewall to prevent dual-use here. And we seem to be promoting defense innovation.

I mean do you share that concern?

MS. WALSH: I do, and yet, as I tried to put in my testimony, the options I think are not great. Again, given that it's a global economy, given that Boeing and other companies on which our own military depends to go out in the world and make money and find new ideas and do business, we're dependent on them doing that as well. So is it the activity that we are concerned about or is it the activity in China?

It seems to me that the options are, you know, constrain that which we've been trying, I think, and it has not worked very well, to sort of muddle through, which has been the default, which I don't think is ideal, or what I try to propose, which is find a way if they're going to do this anyway because they're for-profit businesses and it serves our commercial and defense needs, find a way to better leverage that to know what they're doing, to have the feedback of what's going on there, to basically flood the place. China is, as I said one time I was here before, China is an open market.

Problems, yes, but a door that we can push upon, and I think at this point would probably be our better strategy. Risks involved in all these options, acknowledged, but given, as another said, we've been looking at this for ten, 20 years now, this is not a new problem. We need, I think, perhaps a new answer.

My answer would be to find new ways to leverage this kind of activity so that we know what's going on there, and that we can leverage it back home, and I have not seen nor come up with some new ideas on how to do that yet, but I think if we put our heads together, we could do that, in coordination with industry and academia and government, and find a way to leverage this activity.

DR. MAHNKEN: I'd say balancing national security concerns and commercial concerns is a perpetual challenge. My first job in the federal government was working export control issues surrounding missiles during the Reagan administration so I have very vivid and painful memories of trying to balance those concerns.

But balancing those concerns in the '80s was easy compared to what we

face today because there were some fairly clear lines, there was a fairly clear recognition of what was permissible and what was impermissible. Even then I would argue it was a real challenge, and there were, you know, there were cases back then that were unbelievably hard to resolve, particularly when you looked at them in retrospect and realized it should have been cut and dried.

I think since the end of the Cold War, we've recalibrated that balance between national security and commerce. We may wind up needing to recalibrate that again, and there will be a lot of tradeoffs involved.

COMMISSIONER SLANE: Recalibrated in the benefit of commerce?

DR. MAHNKEN: No, I think we've already been--we're already fairly far over on the commercial side. I guess. Yeah, what I was implying was recalibrating more on the national security front.

Kate raises some important, important questions and some important issues. I mean we really do need to avail ourselves of the skills that China has and some of the capabilities. We may need to think about different ways of doing that.

I think we could do more as a country to get and retain some of the best and the brightest, or more of the best and the brightest here within our borders. We do a wonderful job of educating the world's smartest folks, and then we do a great job of kicking them out the door as soon as they've gotten their degrees rather than welcoming them as say American citizens or permanent resident aliens and keeping more of that intellectual capital here at home rather than letting it go back overseas, for example.

MS. WALSH: Quick anecdote. I mentioned my proposal to a visiting Chinese scholar. He thought that would be frightening for China if we had a strategy to leverage what we're doing in China. So that was his reaction, which I took to be a positive one, that if we actually called their bluff, if you will. Worth considering I'd say.

CHAIRMAN SHEA: Thank you.

I'll ask the next question. Specific military systems. I've read a little bit about unmanned aerial vehicle, Chinese developments, drone technology. I know you grew up around oceanographers. They have a significant submarine program. I mean could you highlight some of the developments in those areas?

DR. MAHNKEN: China, as you know, is and has been quite active in unmanned vehicles, both unmanned aerial vehicles, also unmanned undersea vehicles. A number of my colleagues at the Naval War College and the China Maritime Studies Institute have begun to document some of that interest, and actually going back to my early days in DoD, a good portion of that unmanned vehicle technology is dual-use.

There are unmanned underwater vehicles that are used for oceanographic research, but they also certainly have military applications. For UAVs, there are a host of civilian applications for unmanned aerial vehicles. Of course, we're all, I think, quite familiar with the military applications as well.

Yeah, so that clearly is an area that China is interested in. And, you know, I think it's a growth area worldwide, not just in China. I think China is following that broader global trend.

CHAIRMAN SHEA: Ms. Walsh.

MS. WALSH: I'd just add one thing, on a trip in December to China,I heard, that underwater deep sea exploration technology is an area that China is focusing very

heavily on from talking to somebody who understands Chinese innovation.

Setting up new maritime centers. This is seen not only as dual-use technology, but, of course, also dealing with some of their sovereignty claims in South China Sea and so on is a way around some of those issues. Technology, again, is a solution to some of China's problems. So clearly this is an area they're focused on for a variety of reasons.

COMMISSIONER BARTHOLOMEW: I can't imagine that some of their neighbors are going to be very comfortable about that.

CHAIRMAN SHEA: Commissioner Wessel.

COMMISSIONER WESSEL: Thank you, again.

I'd like to get some information from you, if I can, about the U.S.-China bilateral relationship. You know, clearly, we don't have the full lock on all technology or science in the world. Can you do a quick walk around the world and talk about some of the other relationships that are either providing real opportunities or real challenges with the Chinese?

The UAV was just mentioned, and Israel is probably as advanced as any country, and there have been issues with them and UAVs in the past. We have other technologies, some dual-use, some not, that are providing enormous enhancements. If you have any views on that, I would welcome those comments.

MS. WALSH: Nothing specific. China is, I think, willing to do business, science technology wise, with anyone, and is putting in place the incentives to promote that and draw that. So I don't know why you would limit that. They are willing to work with good actors, bad actors, and others, and so that is strength I think that they have.

As I said, working with a multitude of partners, learning a little bit from everyone, is perhaps a long way about it, but a good way to learn the business.

COMMISSIONER WESSEL: But it's a strength for them. But, again, if we're looking at--as one of the previous panels talked about--potential conflict, and when we talk about defense, we talk about those type of issues, it's not all engagement and not everything is hunky-dory.

What gaps in Chinese capabilities do you see that potentially are being filled by S&T science relationships with other nations that are of concern?

DR. MAHNKEN: Yeah. I think Russia remains one of China's biggest partners in defense, even to an extent that I would personally view contrary to Russia's own interests, commercial interests and potentially in the future national security interests. I mean the Chinese have demonstrated the ability to basically copy Russian technology, Russian aircraft technology, to build their own systems, and yet the Russians will persist in selling combat aircraft to the Chinese.

So I would argue it doesn't make a lot of commercial sense and may in the future not make a lot of national security sense. But the Russians, you know, the Russians continue that pattern of behavior, I think, in part, because it, to a large part, because it's subsidizing the Russian arms industry.

The Russian arms industry used to, you know, really have a domestic market, and exports were sort of an added bonus, at least until recently. The Russian arms industry had to rely on exports to survive.

So I think the Chinese have actually been very effective in using Russian imports, both arms but also knowledge, knowledge transfers and technology transfers to bolster and kind of bootstrap their way up in a number of areas, combat aircraft,

cruise missiles, naval vessels, any number of areas. To me, that's the most prominent example.

You mentioned Israel. There is that. There is in very limited ways and in dual-use ways interactions with Europe and so forth, but to me Russia still is really the key partner in all this.

COMMISSIONER WESSEL: Thank you.

CHAIRMAN SHEA: Commissioner D'Amato.

COMMISSIONER D'AMATO: Thank you, Mr. Chairman.

I'd just like to follow up on something you were just talking about, Dr. Mahnken, on the Russian-Chinese relationship, particularly on the stealth fighter. The stealth fighter was unveiled, you know, under interesting circumstances when Secretary Gates was getting there, and somewhat embarrassing for him and all of that.

Now I'm reading that this may be simply stealth wings on a Sukhoi type 25 or whatever. In other words, is this a Russian cooperative venture, or is this a Chinese adaptation of a Russian fighter with stealth technology wings? The question is whether the stealth technology is Chinese or not? What exactly we've got here, a rabbit or a hare, you know? I'm not sure how significant this particular development was, in hindsight, looking at how it cobbled together the Russian picture.

DR. MAHNKEN: I wish I knew the answer. I trust if I knew the answer, we couldn't talk about it.

[Laughter.]

DR. MAHNKEN: I think there are any, look, there are any number of hypotheses that are out there; right. One is, as you say, cooperation with Russia. Another has to do with technology acquisition, either, the acquisition of components of, our F-117 that was downed over Yugoslavia, or through industrial espionage, gaining knowledge from the U.S. defense industry, or just plain, you know, hard work and elbow grease on the part of the Chinese defense industry, or perhaps all of the above.

You know, it could be a combination of things. It's very hard to tell, and, in fact, it's very hard to tell based on what we know and what's in the open press just how impressive or unimpressive the J20 is.

COMMISSIONER D'AMATO: Yeah.

DR. MAHNKEN: That really would be based on some very, very detailed modeling of radar cross section and so forth, and we just don't have access to that for good reason.

COMMISSIONER D'AMATO: Do you have any thoughts on that?

MS. WALSH: I'd just add that the Chinese-Russian relationship has been, as Tom described, not a very happy one. The Russians have been burned by their Chinese partners when the Chinese turned around and made their own versions of Russian fighters, and yet the Russians are back, trying to do business with the Chinese.

It makes the point that not only in the commercial side, this notion that you cannot not be in the China market, but I think perhaps increasingly on the defense side, the same concept may apply, which is worrisome if that is taking hold. Even if it's against national interests and yet for commercial interests, and they're tied together, that you're going to risk it. And so I'd suggest probably a Chinese adaptation, if past is prologue, and not something that the Russians wanted to hand over willingly, per se, because of international interests, and yet they're willing to take the risk.

If they are, will others? Again, I think this is something better to get in

front of rather than to follow behind constantly, and then surprise is the issue here; right. So you don't want to be surprised. More knowledge, more understanding, being there is worth considering, as I said.

COMMISSIONER D'AMATO: Thank you.

CHAIRMAN SHEA: Commissioner Cleveland.

COMMISSIONER CLEVELAND: I was just looking at your frameworks for analyzing Chinese defense and military innovation, and with Mr. Ross and Mr. Cheung, and it's a terrific way to consider the growth.

That said, I'm going to turn to a study by the National Academy of Sciences, and they talk about China's ambition for self-sufficiency in S&T and provide a checklist of ways to evaluate whether it will achieve its goals.

And as I read them out, what I'm interested in--your view--is which are the most important and why because some of them strike me as silly to me, but probably profoundly important to the Chinese.

The checklist begins with the number of international prizes and patents. That's the first on their list. The emergence of international brands; emergence of innovative products and practice unique to China; the level of R&D expenditures over time; the degree and quality of connections between academic, industry and research centers; the quantity and quality of international collaborations; the amount and type of foreign direct investment; continued growth and improvement in education system and faculty; reduction in corruption; numbers of publications in well-known and prestigious journals; successful expansion of S&T literacy into western China; salaries for scientists and researchers; and trends in brain drain, brain gain and brain circulation.

I know that's a long list, but where, which do you see as perhaps the top three priorities and if we were to evaluate their goal of achieving S&T self-sufficiency and innovation?

DR. MAHNKEN: You're touching on a very important point, and I think one about which experts disagree. I mean there is this question of how do you really measure innovation? It's a crucial question but, again, there's real disagreements.

To my mind, I think some of their criteria are what I would call status criteria, you know, where you can point and say, ahh, we have the most publications or the most patents. You know there is a correlation between patents and innovation, but still it doesn't get to the magnitude of innovation; it doesn't get to a lot of things.

From my mind, the things that I would really be looking at and the things that I do look at are things like governance, so reducing corruption, greater respect for rule of law, greater respect for intellectual property, I mean those are the things to my mind that are really crucial to innovation over the long term, these kind of, you know, it's management, government practices, standards, regulations, things like that. Those are the things that to my mind really are key.

MS. WALSH: I'd agree. I think the qualitative measures are what China is relatively lacking and needs. The quantitative they can do. They mandate it; it's done. And so it is the sort of the soft aspect, the qualitative that they've had trouble with and are still, I think, dealing with. Hard to measure though.

COMMISSIONER CLEVELAND: Thanks.

CHAIRMAN SHEA: Well, I want to thank both of you for your service and for being here and helping to enlighten us on this important subject.

The hearing is adjourned.
[Whereupon, at 3:20 p.m., the hearing was adjourned.]