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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 fabrication 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 multi-national 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 TD-SCDMA, 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.