

U.S.-China Economic and Security Review Commission

Staff Research Report



January 5, 2017

China's Alternative to GPS and its Implications for the United States

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Executive Summary

China's Beidou satellite navigation system is projected to achieve global coverage by 2020, providing position accuracies of under ten meters (one meter or less with regional augmentation) using a network of 35 satellites. While the United States has provided GPS signals to users worldwide for free since the 1980s, China has sought to field its own satellite navigation system in order to (1) address national security requirements by ending military reliance on GPS; (2) build a commercial downstream satellite navigation industry to take advantage of the quickly expanding market; and (3) achieve domestic and international prestige by fielding one of only four such global navigation satellite systems (GNSS) yet developed, cementing China's status as a leading space power and opening the door to international cooperation opportunities. Beidou is consistently referenced as one of China's top space projects in its government white papers on space activities, most recently in December 2016.

China's development and promotion of Beidou presents implications for the United States in security, economic, and diplomatic areas. It is of foremost importance in allowing China's military to employ Beidou-guided conventional strike weapons—the buildup of which has been a central feature of Beijing's efforts to counter a U.S. intervention in a potential contingency—if access to GPS is denied. The concern has also been raised that Beidou could pose a security risk by allowing China's government to track users of the system by deploying malware transmitted through either its navigation signal or messaging function (via a satellite communication channel), once the technology is in widespread use. However, industry professionals interviewed for this report (1) are not aware of ways to feasibly transmit malware through a navigation signal and (2) assess that manufacturers will be unlikely to include the messaging function due to cost factors. Restrictions on technology purchases from China by U.S. government and military users can help guard against malware being physically installed. As Beidou-equipped smartphones become more prevalent, U.S. consumers should know there are no inherent risks to receiving Beidou signals when the satellite communication function is not included.

In economic terms, GPS and Beidou signals are both provided for free and are not in “competition” for market share. Further, experts widely agree that the satellite navigation industry is trending toward “multi-constellation” receivers that work with all GNSS. This development will bring greater accuracy to consumers at minimal marginal cost and is supported by governments around the world. The U.S. firms that currently dominate the downstream satellite navigation industry will thus likely be able to incorporate Beidou functionality and continue to compete both in China and the global market, despite steps China has taken to protect its companies in the industry. China's subsidies and preferential taxation policies pose a larger problem, as these are likely to primarily benefit domestic companies. Further, state-affiliated customers in China will probably avoid U.S. technologies once China's industry becomes mature. This development will likely narrow opportunities for U.S. firms in the long term, as has been typical of non-Chinese firms' experience in the China market across a wide range of industries.

Finally, Beidou will likely bring enhanced prestige and diplomatic opportunities for China's government. The system could provide Beijing with leverage to obtain more influence in several international and regional organizations that deal with global satellite navigation issues. Further, China plans to expand Beidou coverage to most of the countries covered in its “One Belt, One Road” initiative by 2018, indicating it sees the system as playing a role in its economic diplomacy efforts. China has also sought to incentivize nearby countries, most notably Thailand, to begin using Beidou receivers, and seeks access to build a network of differential ground stations throughout Asia—perhaps 1,000 in Southeast Asia alone—to improve the system's accuracy and, by extension, Chinese companies' commercial prospects. These stations will not have a direct effect on U.S. regional influence or U.S. firms in downstream industries (which can also build receivers that utilize them), should trends towards interoperability continue.

In response to these developments, the United States can: consider allowing government and military users to take advantage of multi-constellation devices, continuing to monitor the industry to assure that security threats do not materialize; promote interoperability to ensure its firms remain competitive; and continue to invest in maintaining its leadership in space.

Introduction

Since 1994 China has spent billions of dollars to develop a product that is already free: satellite navigation services provided globally by the U.S. Global Positioning System (GPS). This report examines the objectives behind Beijing's decision to develop the Beidou system as an alternative to GPS, its efforts to build an industry around the system, and the effects this might have in security, economic, and diplomatic terms for the United States. As China nears its goal of providing global satellite navigation coverage by 2020 and growing numbers of Beidou-configured products enter the vast downstream market, considering these implications will become increasingly important.

Background: Satellite Navigation and its Impacts

Global Navigation Satellite Systems (GNSS), which GPS and its predecessor systems pioneered, provide positioning, navigation, and timing (PNT) information by broadcasting radio signals to devices on the ground. In the case of GPS, receiving these signals from at least four satellites at different points in a GNSS constellation allows the calculation of the receiver's location, velocity, and local time.*¹ Four such systems are currently in development or operation:

- The United States' **GPS**, initiated in 1978[†] and achieving global coverage in 1995.² GPS typically provides positioning accuracies of under 2.2 meters, which can be improved to as low as a few centimeters with the use of augmentation systems.³ Ground-based augmentation systems rely on a network of ground stations to boost accuracy,⁴ while satellite-based augmentation systems use a different network of satellites to do so.⁵
- Russia's **Global Navigation Satellite System (GLONASS)**, initiated in 1982 and achieving global coverage in 1996, and again in 2011 (after the system had fallen into disrepair).⁶ GLONASS provides positioning accuracies of 2.8 meters, and Russia is developing a satellite-based augmentation system primarily focused on Russian territory.⁷
- The European Space Agency's **Galileo** system, initiated in 2005 and projected to provide global coverage by 2020.⁸ Galileo will provide positioning accuracies of one meter with its open service and one centimeter with its restricted commercial service.⁹
- China's **Beidou** system, initiated in 1994 and projected to provide global coverage by 2020.[‡]¹⁰ Beidou will reportedly provide positioning accuracies of under ten meters worldwide, improving to one meter or even less with the use of a forthcoming ground-based augmentation system focused on China.¹¹

GPS began as a U.S. military project and has had a transformative impact in the global security realm. Military strategists identify space-based PNT as a significant factor in the "Revolution in Military Affairs (RMA)"[§] that began in the early 1990s, one of only a handful of such revolutions that have transformed warfare throughout history. A GNSS specifically allows the guidance of sensor-equipped platforms and missiles to precise positions, creating a "reconnaissance-strike complex" when combined with advances in gathering and disseminating information and in command and control.¹² The development of precision-guided munitions in large quantities has been the central feature of China's "antiaccess/area denial (A2/AD)" objective within its People's Liberation Army (PLA) missions,** intended to make a U.S. military intervention in the Western Pacific more costly. GPS, Galileo,

* The time elapsed between sending and receipt, multiplied by the standard rate at which these radio waves travel, yields the distance from each satellite to the receiver. These distances are then used to determine location through the geometric method of trilateration. National Coordination Office for Space-Based Positioning, Navigation, and Timing, *Trilateration Exercise*, November 25, 2014. <http://www.gps.gov/multimedia/tutorials/trilateration/>.

† The beginning year listed is the year in which the first satellite associated with the program (including test satellites) was launched.

‡ India and Japan have also begun navigation satellite system programs, but these are intended to complement or back up existing GNSS systems in certain regions rather than to provide global coverage on their own. Government of Japan Cabinet Office, *What is the Quasi-Zenith Satellite System (QZSS)?*; Ishan Srivastava, "How Kargil Spurred India to Design Own GPS," *Times of India*, April 5, 2016.

§ According to analysts at the Strategic Studies Institute of the U.S. Army War College, "most analysts define a RMA as a 'discontinuous increase in military capability and effectiveness' arising from simultaneous and mutually supportive change in technology, systems, operational methods, and military organizations." James Kievit and Steven Metz, "Strategy and the Revolution in Military Affairs: From Theory to Policy," *Strategic Studies Institute*, June 1, 1995, vi, 7. <http://www.au.af.mil/au/awc/awcgate/ssi/stratma.pdf>.

** According to the U.S. Department of Defense, "antiaccess" actions are intended to slow the deployment of an adversary's forces into a theater or cause them to operate at distances farther from the conflict than they would prefer. "Area denial" actions affect maneuvers within

GLONASS, and Beidou each have a restricted signal that provides higher accuracies,¹³ reflecting the ongoing military impact of GNSS. U.S. experts and defense officials have also argued that configuring military systems to work with multiple GNSS, an approach known as “diversification,” could help back up GPS in the future.¹⁴

GPS and follow-on systems have had revolutionary commercial impacts as well. Even before GPS was declared operational, industry developed ways to exploit it for high precision surveying and other professional applications. Since the United States ended the intentional downgrading of public GPS signals in 2000,^{*} ¹⁵ downstream consumer industries have developed rapidly: personal navigation assistants used while driving, followed by in-dash systems pre-installed in automobiles, followed by applications for smartphones and other devices, with new trends including GNSS-equipped wearable technology and autonomous vehicle navigation.¹⁶ These developments have occurred in a surprisingly short period of time, yielding an industry worth \$82.4 billion in 2014 and forecast to grow 7 percent annually on average through 2023, with 3.6 billion GNSS devices in use worldwide.¹⁷ Today’s GNSS downstream industry can be broadly divided into (1) component manufacturers, which produce receivers for stand-alone use or integration into systems; (2) system integrators, which integrate GNSS capability into larger products such as vehicles, consumer electronics, and personal navigation assistants; and (3) value-added service providers, which offer GNSS-enabled software such as maps, telecommunications, and location-related data downloads (e.g. Google Maps, Waze, Uber, Skype, and any weather application).¹⁸ As of 2012 the United States led with 31 percent of the total downstream market, followed by Japan with 26 percent, Europe with 25.8 percent, and China with 7 percent. The GNSS market is highly consolidated, particularly at the level of component manufacturers.[†] ¹⁹

Lastly, the global downstream GNSS industry is moving rapidly towards “multi-constellation” devices, built to receive signals from two, three, or all four of the GPS, GLONASS, Galileo, and Beidou systems.²⁰ The European Global Navigation Satellite Systems Agency’s 2015 market report notes that “almost 60 percent of all available receivers, chipsets and modules are supporting a minimum of two constellations, showing that multi-constellation is becoming a standard feature across all market segments” (GPS is included in one hundred percent of these multi-source devices).²¹ U.S. company Qualcomm Inc., the leading global manufacturer of satellite navigation components, has produced chips that support GLONASS (along with GPS) for roughly the past four years, Beidou for roughly two years, and Galileo for roughly one year.²² This trend is being driven by technical, economic, and political factors:

- The multi-constellation feature will likely provide consumers with greater reliability and accuracy than a single GNSS can provide, especially in urban environments,²³ meaning that single-constellation devices will probably not be competitive in the future, except in the most cost-constrained markets.²⁴
- Although there are incremental software development costs in adding new constellations for receiver chipset manufacturers, there is little extra hardware cost, and the software can largely be reused in future products.²⁵
- This development is actively supported by governments around the world: the ultimate goal of the International Committee on GNSS of the UN Office of Outer Space Affairs is “to achieve compatibility and interoperability of GNSS systems;”[‡] ²⁶ the United States officially seeks to “engage with foreign GNSS

a theater, and are intended to impede an adversary’s operations within areas where friendly forces cannot or will not prevent access. U.S. Department of Defense, *Military and Security Developments Involving the People’s Republic of China 2013*, 2013, i, 32, 33; U.S. Department of Defense, *Air-Sea Battle: Service Collaboration to Address Anti-Access & Area Denial Challenges*, May 2013, 2.

* According to official U.S. policy, the United States has no intention of ever resuming this intentional downgrading, and the next generation of GPS satellites will not even have this capability. In a case in which the United States desired to prevent a potential adversary from using GPS, the U.S. military “is dedicated to the development and deployment of regional denial capabilities in lieu of global degradation.” National Coordination Office for Space-Based Positioning, Navigation, and Timing, *Selective Availability*, September 23, 2016. <http://www.gps.gov/systems/gps/modernization/sa/>; National Coordination Office for Space-Based Positioning, Navigation, and Timing, *Frequently Asked Questions Regarding Selective Availability*, September 24, 2013. <http://www.gps.gov/systems/gps/modernization/sa/faq/#dgps>.

† For examples of leading companies in these sectors, as of 2012 Qualcomm (U.S.), Trimble Navigation (U.S.), and Broadcom (U.S.) were the three leading component manufacturers; Toyota (Japan), Garmin (Switzerland), and General Motors (U.S.) were the leading system integrators—Apple (U.S.) and Samsung (Korea) were also top 10 players—and Google (U.S.), Pioneer (Japan), and Denso (Japan) were the leading value-added service providers, with Microsoft (U.S.) also in the top 10. European Global Navigation Satellite Systems Agency, *GNSS Market Report 4* March 2015, 11. http://www.gsa.europa.eu/system/files/reports/GNSS-Market-Report-2015-issue4_0.pdf.

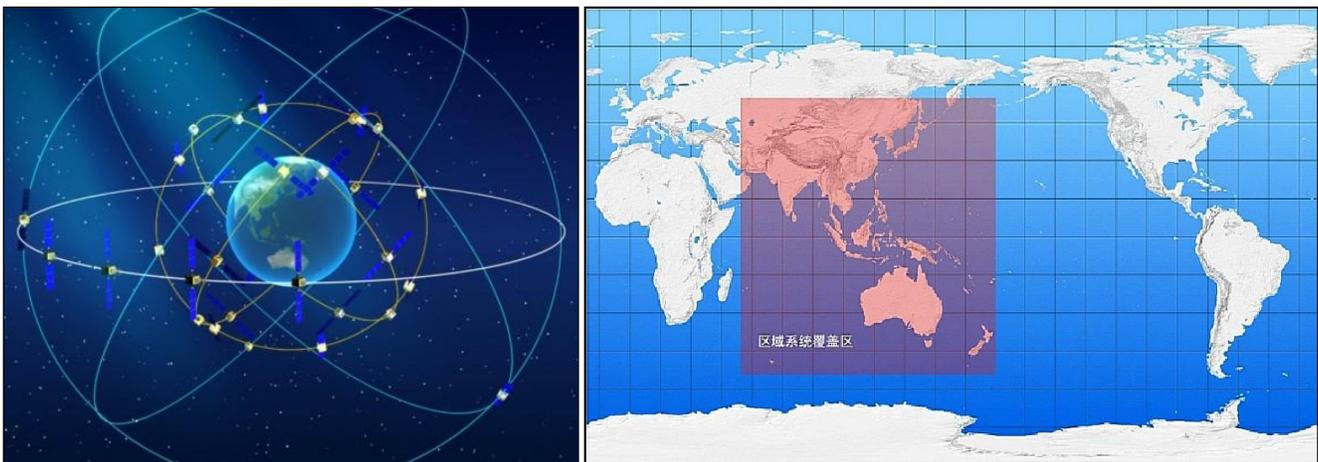
‡ The UN Office for Outer Space Affairs defines “compatibility” as “the ability of global and regional navigation satellite systems and augmentations to be used separately or together without causing unacceptable interference and/or other harm to an individual system and/or

providers to encourage compatibility and interoperability” and to encourage the use of foreign PNT services “to augment and strengthen the resiliency of GPS;”²⁷ and Chinese officials have also expressed support for interoperability, including in the government white paper on Beidou released in 2016.²⁸ The United States and China began bilateral consultations on civil cooperation related to GPS and Beidou in 2014.²⁹

China’s Objectives for the Beidou System

Beidou today features 23 satellites in medium Earth and geosynchronous orbits,³⁰ providing regional coverage at accuracies of under ten meters (a separate military signal likely provides higher accuracies).³¹ Chinese officials state that when complete, Beidou will consist of 35 satellites and provide positioning accuracies of under ten meters worldwide, improved in China to one meter and even centimeters in some areas with the use of a forthcoming “differential Beidou” system, which will use a network of thousands of ground stations to boost accuracy.³² China also aims to develop a global satellite-based augmentation system in the future, and has stated its desire that this be interoperable with other countries’ augmentation systems.³³ China announced in May 2016 that it would launch a total of 30 Beidou satellites during the 13th Five Year Plan period (2016-2020) to reach this objective (satellites become defunct and must be replaced, accounting for the discrepancy).³⁴ China reportedly spent \$2.57 billion on the Beidou program from 1994 to 2012 and planned (as of 2013) to spend an additional \$6.41-\$8.02 billion from 2013 to 2020, indicating it is one of the largest space programs the country has undertaken. Beidou is also one of China’s 16 “megaprojects” under the 2006-2020 Medium and Long-Term Plan for Science and Technology Development.³⁵ It is consistently referenced as one of China’s top space projects in its government white papers on space activities, most recently in 2016.³⁶

Figure 1: Diagram of Future Beidou Constellation and Current Coverage



Source: China Satellite Navigation Office, “Beidou: Bring the World and China to Your Doorstep” (5th Session of the Committee on the Peaceful Uses of Outer Space, UN Office for Outer Space Affairs, Vienna, Austria, June 6-15, 2012). <http://www.oosa.unvienna.org/pdf/pres/copuos2012/tech-07.pdf>.

Just as GPS was originally driven by military objectives, China made the determination to develop Beidou based on perceived security requirements, as described in the Commission’s 2015 Annual Report to Congress:

service.” It defines “interoperability” as “the ability of global and regional navigation satellite systems and augmentations and the services they provide to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system.” United Nations Office for Outer Space Affairs, *International Committee on Global Navigation Satellite Systems (ICG): Providers’ Forum*, 2016. <http://www.unoosa.org/oosa/en/ourwork/icg/providers-forum.html>.

* Medium Earth orbit is the classification of orbits between 1,200 and 22,300 miles above the Earth’s surface. At semisynchronous orbit (about 12,400 miles), satellites circle the Earth every 12 hours, ideal for precision timing and navigation satellites. Geosynchronous Earth orbit can be achieved at about 22,000–23,000 miles above the Equator. The highest orbital band within this classification in frequent use is known as “geostationary Earth orbit.” At this altitude, satellites move at the same speed as the Earth’s rotation, enabling them to cover large geographic areas. Beidou includes satellites in medium Earth orbit, inclined geosynchronous orbit, and geostationary Earth orbit. State Council Information Office of the People’s Republic of China, *China’s Beidou Navigation Satellite System*, June 2016. http://english.gov.cn/archive/white_paper/2016/06/17/content_281475373666770.htm.

The PLA has considered [its] dependence on a foreign PNT system to be a strategic vulnerability since at least the mid-1980s. These fears were exacerbated during the 1995–1996 Taiwan Straits Crisis. According to a retired PLA general, the PLA concluded that an unexpected disruption to GPS caused the PLA to lose track of some of the ballistic missiles it fired into the Taiwan Strait during the crisis. He then said that ‘it was a great shame for the PLA ... an unforgettable humiliation. That’s how we made up our mind to develop our own global [satellite] navigation and positioning system, no matter how huge the cost. Beidou is a must for us. We learned it the hard way.’³⁷

China undertook its massive effort to build a commercial industry compatible with the system later, after the U.S. government stopped degrading the civil GPS service in 2000 and the commercial potential of GNSS became fully evident. In an indication that the commercial driver has become highly important, the 2016 government white paper on Beidou calls for the implementation of central, state, and local policies to support the development of Beidou applications and industrial products; investment in applying Beidou technologies and products to “key sectors related to national security and [the] economy;” and investment in research and development of “chips, modules, antennae and other basic products” to be used with Beidou and other compatible systems—ultimately seeking to build an “industrial chain” comprising all parts of the downstream industry. The white paper also announced officially for the first time that Beidou (like GPS) would be free to all users worldwide.³⁸ In 2013 China publicly released Beidou’s interface control document, containing the technical information required to develop receivers compatible with the system,³⁹ as was done for other GNSS.

The total output of China’s navigation services sector exceeded \$25 billion (173.5 billion renminbi) in 2015 and is expected to top \$58 billion (400 billion RMB) in 2020, according to the most recent white paper published by the Global Navigation Satellite System and Location Based Services Association of China. This represented a year-on-year growth rate of 29 percent, with 20 to 30 percent growth rates predicted for the coming years. The white paper also noted that 466 million PNT end products, including 440 million smartphones, were sold in China in 2015 alone. The market penetration of Beidou is close to 20 percent, but the document states that it is expected to reach 60 percent by 2020.⁴⁰ According to Davof Xu, GNSS China Project Manager for the European Union Chamber of Commerce in China, there are over 14,000 companies and organizations active in the GNSS-related industry in China, accounting for a total of more than 450,000 employees.⁴¹ The industry’s rapid growth along with China’s relatively low current market share, latecomer status, and fragmented market (Chinese GNSS companies are mostly small- and medium-sized in comparison to highly consolidated global providers⁴²) likely indicates to Beijing an opportunity for significant economic benefits down the road.

Beidou’s development thus far indicates several key political objectives as well. China’s leadership views its efforts in space as providing both domestic and international prestige,⁴³ and the development of one of the world’s first satellite navigation systems is likely seen as a main contributor in this regard. Officials have been quick to tout occasions in which receivers in various fields utilize “China’s own Beidou system.”⁴⁴ One 2015 state-run media report emphasized that 98 percent of the components in the newest Beidou satellites were made in China, with international commenters noting that this domestic sourcing demonstrated China’s status as a leading space power.⁴⁵ At the technical level, Beidou offers a short messaging service through which messages of up to 120 characters can be sent to other Beidou receivers, unlike GPS.⁴⁶ Via this service, Chinese fishing vessels are reportedly able to sound “instant alarms” to fishing departments when emergencies arise, while a supplementary “vessel management system” allows them to request assistance from nearby vessels.⁴⁷ This feature is particularly relevant to the ongoing disputes in the South China Sea, where fishing rights are at stake and where China’s maritime militia—a quasi-military force of fishermen that are tasked by and report to the PLA—plays a key role in advancing Beijing’s claims.⁴⁸ The international cooperation opportunities provided by Beidou have also become a tool for Beijing to use within its larger foreign policy approach, as discussed further below.

Preferential Policies to Promote Beidou

While Beidou is provided for free and does not “compete” with other satellite navigation systems, Beijing has undertaken a host of domestic policies to promote the adoption of Beidou-compatible receivers and expand its GNSS industry. Most notable are rules requiring the installation of Beidou receivers on 80 percent of all buses and trucks in nine provinces (out of 34 provincial-level administrative units total), mandating that new heavy trucks and

semi-trucks have factory-installed Beidou receivers,⁴⁹ and offering subsidies for the purchase of shipborne Beidou receivers for fishing boats.⁵⁰ For context, Russia has mandated the use of GLONASS across a range of sectors, including “critical infrastructure” and government applications,⁵¹ and Europe has considered mandates for Galileo;⁵² the United States recommends technology-neutral, performance-based standards.⁵³ However, Beijing has also pledged funding for various sectors of the industry in numerous government plans, most notably the 2013 National Navigation Satellite Industry Medium- and Long-Term Development Plan, which states that China will seek to have its companies capture 60 percent of the domestic GNSS applications market (and 80 percent of “important” applications) and become globally competitive by 2020. The plan also encourages the improvement of financial and taxation policies to help domestic firms in the industry expand to international markets.⁵⁴ Provincial governments have issued plans for satellite navigation industry development as well; Henan’s June 2016 plan calls for fiscal and tax policy support, the establishment of industrial parks, and government procurement support, particularly for products from the province.⁵⁵

At the international level, China has sought to incentivize nearby countries to begin using Beidou receivers, in order to prove the technology’s viability and prepare its companies to compete globally in the future. This began when China signed a roughly 2 billion yuan (\$297 million) agreement with Thailand in 2013, reportedly funded mostly by Beijing as part of its foreign aid program, to promote the use of Beidou in Thailand’s public sector in areas such as disaster relief, power distribution and transportation.⁵⁶ According to one Chinese academic expert, Beijing saw Thailand as an ideal starting point as its heavy reliance on GPS would allow China to demonstrate that “Beidou can do anything GPS does;” one official additionally stated that “to cooperate with Thailand . . . is to bring Beidou to Southeast Asia.”⁵⁷ China has since reached agreements with Brunei, Laos, and Pakistan to provide Beidou-equipped infrastructure for government and military users, also at heavily subsidized costs. These agreements have included provisions allowing China to build differential ground stations in each country to increase the system’s accuracy on the ground.⁵⁸ China has also been in talks with several countries in the Middle East, including Saudi Arabia and Egypt, regarding assistance from Beijing in introducing Beidou-based services, and the first “China-Arab States Beidou Cooperation Forum” is planned for 2017.⁵⁹ China has stated it plans to expand Beidou coverage to most of the countries covered in its “One Belt, One Road” initiative* by 2018 on the way to global coverage in 2020,⁶⁰ and has emphasized these countries in its promotion efforts.⁶¹ Lastly, China and Russia have agreed to establish a joint venture to develop and market satellite navigation devices compatible with Beidou and GLONASS. Additionally, each country will establish three differential stations in the other country.⁶²

Implications for the United States

The original military purpose of Beidou and China’s current diplomatic and commercial efforts involving the system present important implications for the United States.

Military and Security Implications

If, as projected, Beidou achieves global coverage by 2020, China’s military will complete its shift away from reliance on GPS for precision strike. Beidou’s initial deployment has already been focused on providing coverage in the Asia Pacific region (as shown in Figure 1), the area in which China’s ground-, air-, and sea-launched missiles would likely be employed in a counterintervention scenario. Public information about China’s incorporation of Beidou into its weapons systems is scarce, as the Commission noted in its 2015 Annual Report to Congress, but China is almost certainly equipping its ballistic and cruise missiles to operate with both GPS and Beidou. If true, PLA operators could switch to Beidou to guide a missile to its target if GPS were denied, and China would also be able to attack an adversary’s access to GPS without disrupting its own capabilities. The PLA has likely also been using Beidou for positioning and maneuvering, friendly force tracking, and secure communications since the late 2000s.⁶³ Most military facilities, lighthouses, and fishing boats have been using the system since 2012, according to Chinese officials.⁶⁴ In the long term, should China succeed in developing its downstream GNSS industry, the

* President Xi Jinping’s “One Belt, One Road” initiative involves major infrastructure projects in ports and railways throughout the region. It is composed of a land-based “belt” through Central Asia and a maritime “silk road” counterpart that will run through Southeast Asia and the Indian Ocean to Africa and the Mediterranean Sea. U.S.-China Economic and Security Review Commission, *2015 Annual Report to Congress*, November 2015, 168.

PLA will additionally have its own domestic “industrial chain” on which to draw for secure components. In 2015 private Chinese firm Alibaba and state-owned defense conglomerate China North Industries Corporation (NORINCO) formed a joint venture worth roughly \$310 million to “build applications and technology to support and work with the [Beidou] system,” indicating China is already seeking to leverage civil-military integration in GNSS.⁶⁵

Concerns have also been raised regarding inherent security vulnerabilities in Beidou-equipped receivers. For example, Taiwan’s Ministry of Science and Technology stated in a report to the country’s legislature in May 2016 that Beidou can “track” smartphone users via embedded malware in devices containing Chinese-manufactured satellite navigation chips, and thus poses an information security risk to Taiwan.⁶⁶ It is of course already possible to track a GPS-equipped device (using the “Find My iPhone” application, for example); this concern would involve a device’s location being shared unknowingly due to malware. The Taiwan government report mentions that in the case of Beidou such malware could originate from chips manufactured by Chinese companies or from the Beidou navigation signal or messaging service directly (similar to recent instances of malware distribution via SMS text messages).⁶⁷ The report announced a range of measures across military and commercial sectors to address this vulnerability, including requiring distributors to identify products equipped for use with Beidou, compiling a list of Beidou-compatible applications and testing them for malware, calling on civil servants to avoid buying or using products or applications that use Beidou, monitoring the Beidou signal to detect anomalies that might indicate a hack, and considering a ban on the import and sale of Beidou-equipped devices entirely.⁶⁸ The 2017 National Defense Authorization Act bans the U.S. military from using any “non-allied” PNT system (i.e. GLONASS or Beidou) for a period of time absent a waiver from the U.S. Secretary of Defense, and requires an assessment of the risks of utilizing such systems by April 22, 2017,⁶⁹ indicating this is a pressing question in the United States as well.

Technical experts interviewed for this report, however, noted that (1) they are not aware of ways to feasibly transmit malware through a navigation signal; and (2) receiver chip manufacturers will be unlikely to include the “texting service” due to cost factors.⁷⁰ Jim Mollenkopf, Senior Director of Strategic Development for Qualcomm Government Technologies, stated that “Qualcomm’s products only use Beidou for passive reception of navigation signals, and do not use the Beidou messaging function. We know of no way for the Beidou system to track users without the messaging function enabled.”⁷¹ David Stelpstra, a geodetic engineer at Dutch company TomTom NV, noted that transmission requires a great deal of power and manufacturers would not want to include this feature, as battery capacity is a bottleneck for portable navigation devices.⁷² Another engineer concurred, stating:

If the hardware is ‘receive only,’ there is no way to transmit. Adding transmit would double the cost and complexity, so most chip manufacturers would not implement it, except for the China-specific brands for the [Chinese] fishing vessels and other very specialized systems. So the answer is yes, there could be a security risk, but that would track a very limited band of people that are likely locals anyways.⁷³

Thus, should global manufacturers avoid including the Beidou messaging service as predicted, and should U.S. government buyers avoid using products manufactured by Chinese companies with a higher risk of malware being physically installed, these security vulnerabilities would be mitigated. In addition, U.S. military systems may be able to safely utilize a diversity of PNT systems in the future, pending military and intelligence community confirmation of these private sector assessments. Lastly, given that one-third of the smartphones exported from China in the first quarter of 2016 reportedly contained Beidou receiver chips,⁷⁴ U.S. consumers should know that there are no inherent risks involved in a smartphone having Beidou connectivity if it does not include the satellite communication channel. However, the risk of malware being installed if a Chinese company is the original

* Mr. Mollenkopf provided the following more detailed technical explanation of why this is the case: “For Beidou to introduce malware to a smartphone, the Beidou navigation signal would need to somehow be converted to program code without being rejected as corrupt (unlikely), and then the phone would need to be crashed and somehow vectored to look into GNSS system memory for software program instructions (probably through some other non-Beidou mechanism) and then run the offending code to create a malicious effect. Qualcomm’s products include a number of measures to prevent each and every step in this chain of events and we consider it exceedingly unlikely.” Mr. Stelpstra agreed, noting that “the encryption of malware in the navigation messages is highly unlikely because this will alter the transmitted orbits and therefore make the use of that satellite impossible for position determination of the receiver.” Jim Mollenkopf, Senior Director, Strategic Development Qualcomm Government Technologies, interview with Commission staff, October 14, 2016; David Stelpstra, Geodetic Engineer, TomTom NV, interview with Commission Staff, October 14, 2016.

equipment manufacturer of the smartphone (unlike those that dominate the U.S. market today) should be carefully considered.

Diplomatic Implications

As the Commission noted in its 2015 Report, Beidou's achievement of global coverage could provide Beijing with leverage to obtain more influence over PNT-related decisions in several international and regional organizations that deal with these issues, such as the International Telecommunications Union, the International Committee on Global Navigation Satellite Systems, the Asia-Pacific Economic Cooperation forum, and the International Civil Aviation Organization.⁷⁵ In 2014 the International Maritime Organization—the UN agency that sets safety standards for international shipping⁷⁶—approved a Beidou-equipped receiver for the first time, viewed by China as a milestone in its pursuit for the system's international adoption.⁷⁷ As with other major space projects, Beidou's achievements should be expected to benefit the prestige and soft power aims of China's government, particularly as it reaches parity in a longstanding area of U.S. dominance.

Beyond providing influence in international organizations, Beidou will likely contribute to China's broader foreign policy approach toward specific countries and regions in its early days as a global system. China's statement that it plans to expand Beidou coverage to most of the countries covered in its "One Belt, One Road" initiative by 2018 indicates that it sees the system as playing a role in its economic diplomacy efforts. Beijing's January 2016 "Arab Policy Paper" specifically identifies plans to accelerate the application of Beidou services to Arab countries as contributing to Beijing's regional infrastructure development and space cooperation objectives.⁷⁸ Mr. Xu assesses that countries in Asia desire to avoid reliance on GPS alone,⁷⁹ a demand China can meet with its free alternative. This demand may extend to military systems equipped with Beidou as well, meaning U.S. suppliers may need to produce both Beidou- and non-Beidou-equipped products if buyers such as the United States government restrict the use of non-allied GNSS in their military systems. Otherwise, once Beidou has gone global and multi-constellation devices have become the norm, Beijing's ability to reap continued diplomatic benefits will likely be limited.

Importantly, in many cases China's engagement is likely intended not for broader diplomatic aims but to facilitate Beidou's practical requirements. One example is Beijing's plan to construct a network of differential ground stations throughout Asia—perhaps 1,000 in Southeast Asia alone⁸⁰—to increase the system's local accuracy.⁸¹ These stations are likely to be a standard component of all GNSS going forward, and will not have a direct effect on U.S. regional influence or commercial interests should trends towards interoperability continue. However, U.S. legislation passed in 2013 prevents foreign ground monitoring stations from being installed on U.S. soil, unless it can be certified that they "will not possess the capability or potential to be used for the purpose of gathering intelligence in the United States or improving any foreign weapon system."⁸² Russia shut down U.S.-provided science community GPS stations on its soil in 2014, ostensibly in retaliation for its inability to install differential ground stations for GLONASS in the United States,⁸³ indicating that Beidou stations may also prove to be a source of diplomatic tension.

Commercial Implications

The global trend toward product compatibility with multiple constellations may actually create additional opportunities for U.S. companies in China in the near term, as assessed in a report by the University of California Institute on Global Conflict and Cooperation (IGCC) released by the Commission in July 2016. Qualcomm provided the GNSS component technology for the first GPS- and Beidou-compatible smartphone—the China market version of the Samsung Galaxy Note 3—in 2013, for example.⁸⁴ China's public release of Beidou's interface control document (as done with other GNSS) indicates a desire for some level of international participation, and an official with the China Satellite Navigation Office noted in 2014 that "Chinese companies can only grow by engaging in face-to-face competition with the world's top companies in the industry."⁸⁵ It is important to note, however, that it takes roughly one to two years to add a new constellation to product software,⁸⁶ a disadvantage for foreign companies that have not yet developed Beidou compatibility, and that China's government has still taken steps to protect its companies:

- Chinese companies were given early access to Beidou reference designs and specifications, providing an early advantage in developing Beidou products
- China has established certification hurdles seemingly targeting non-Chinese vendors⁸⁷
- Qualcomm was not allowed to join China's GNSS standards committee alongside domestic firms⁸⁸

It will thus likely take time for U.S. firms in China's domestic market to take advantage of the commercial shift toward multi-constellation devices, although this trend has the potential to eventually reduce the impact of Beijing's mandates.

In the long term, a far different outlook emerges. China's preferential financial and taxation policies aimed at promoting Beidou are likely to negatively impact U.S. companies operating in China's market, according to the IGCC report, as most of these incentives are likely to be given primarily to local Chinese companies. Of greater concern, U.S. suppliers will likely be replaced by local ones for Chinese government and military users seeking "secure and controllable" options. The report states that it is unclear how broadly this typically occurs in the civilian market, but the long-term outcome for U.S. firms in the industry will likely be negative.⁸⁹

In the international market, U.S. companies will likely be able to configure their products to work with the constellations prevalent in each region and compete with fewer obstacles than in China's domestic market. From this perspective, rapid movement towards full interoperability between satellite navigation systems will continue to be in the interests of the United States. Challenges specific to the downstream satellite navigation industry in China should be included in larger discussions regarding U.S.-China trade and market access issues. As Mr. Xu observes, market access for foreign firms in China is a "general not a particular problem."⁹⁰

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