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A Risk-Benefit Analysis of China's Belt and Road Initiative Spatial Information Corridor

Implications for Chinese Global Expansion and US Strategy

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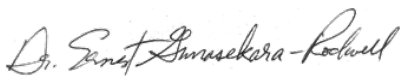
Foreword

The Kenney Papers series from Air University Press, in collaboration with the Consortium of Indo-Pacific Researchers, provides a forum for topics related to the Indo-Pacific region, which covers everything from the western shores of the Americas to the eastern coast of Africa and from Antarctica to the Arctic. Named for General George Churchill Kenney, Allied air commander in the Southwest Pacific during World War II and subsequently commander of Strategic Air Command and then Air University, this series seeks to provide a deeper understanding of the region, the geopolitics and geoeconomics that shape the theater, and the roles played by the US military in providing for a free and open Indo-Pacific.



DR. ERNEST GUNASEKARA-ROCKWELL
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Abstract

At the turn of the century, competition in space shifted from being between the United States and the Soviet Union to being between the United States and China. Since its first manned mission in 2003, China's space program has accelerated dramatically. China completed the BeiDou System satellite constellation in 2020, its own Global Navigation Satellite System, sent a rover to the far side of the Moon in 2019 and to Mars in 2021, and is assembling its own space station with completion targeted in 2022. While the United States is still dominant in space, China's rapid development concerns the U.S. military.

Due to the military-civil dual-use nature of space activities, as China's space capability develops it can also be viewed as development of its military capability in space, thereby complicating the geopolitical competition between the United States and China. The question that emerges is: How will China's space capabilities enhance its global influence? More specifically, will BDS shift the current power distribution between the two countries toward China in the South China Sea, a crucial hot spot over which the two powers compete?

In this study I try to answer such questions by focusing on the Belt and Road Initiative Spatial Information Corridor, which includes China's most obvious geopolitical space-related activities and provides space-related services to members of the Belt and Road Initiative. BRI–SIC projects are the least studied of all BRI projects. By conducting a risk-benefit assessment of 108 BRI–SIC projects, I explore a more specific question: Should the United States and its allies be concerned with China's global expansion of space-related activities in the name of BRI–SIC?

This question is answered affirmatively based on this study's assessment. Concerns among the United States and its allies ought not stem from the BRI–SIC being designed to benefit China's global military strategy due to the military-civil dual-use nature inherent to space-related activities and technologies. Rather, concerns are due to the economic and political influence that BRI–SIC can provide to China. BRI–SIC projects benefit their host nations. Specifically, 100% of the identifiable projects are beneficial infrastructure enablers, and 76.6% can strengthen the human security of the host. While some projects carry potentially high national security risks, developing countries acting as host nations are undeterred, as the priority is to develop the economy. China is able to convert the beneficial nature of the BRI–SIC into leverage over the recipient host nations to enable China to establish its own ecosystem in the space-related data/information domain.

Currently, the United States and its allies need not be concerned that the BRI–SIC enhances China's military or spacefaring capabilities. Rather, they need to be aware that the BRI–SIC is sowing seeds for Chinese space-related vendors, particularly for those dealing with the BeiDou System, to permeate BRI markets in the future. Because BRI host nations possess huge market potential due to faster rates of economic development and greater vulnerability to climate change, China is positioned to harvest the fruits of this endeavor unless the United States and its allies provide attractive alternatives to host countries.

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I greatly appreciate the opportunity to publish this contribution to the Kenney Papers series under the auspices of Air University Press and thank the hardworking AUP staff who brought this work to publication. During my career I have benefited from the support of numerous organizations and individuals, and I am especially grateful for the continuous support of the Reischauer Center at the School of Advanced International Studies, Johns Hopkins University, and its Director and the former SAIS Dean, Professor Kent Calder. Professor Scott Pace, the Director of Space Policy Institute, George Washington University, has provided and continues to provide me with a wealth of expertise and support. I thank Dr. Brian Weeden and Ian Christensen at Secure World Foundation, both of whom shared their rich knowledge and insights. I also thank Stephanie Wan and Professor Kazuto Suzuki, along with the many other people who have influenced my research.

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Her current research focuses on how China is using its rapidly developing space capabilities to affect the outcomes of the South China Sea disputes to its favor. Prior to this research focus, she studied internet and politics, which generated several academic journal publications, and Japanese nationalism. Her book *Nationalism, Political Realism, and Democracy in Japan: The Thought of Masao Maruyama* assesses the development of democracy in postwar Japan through the writings of the brilliant political thinker.

Dr. Sasaki received a PhD and MA in Asian Studies and International Relations from SAIS. She frequently lectures on Asian security issues and has appeared as an expert in various media, including *The Economist*, *Harvard International Review*, *Georgetown Journal of International Affairs*, *South China Morning Post*, *The Strait Times*, *The Diplomat*, and *China Newsweek*.

Key Findings

To date, the US and its allies need not be concerned that the Belt and Road Initiative–Spatial Information Corridor enhances China's military or space-faring capabilities. Rather, they need to be aware that the BRI–SIC is sowing seeds for Chinese space-related vendors, particularly those for the BeiDou System, to permeate BRI markets in the future. Because BRI host nations possess huge market potential due to faster economic development and vulnerability to climate change, China is positioned to harvest the fruits thereof unless the US and its allies provide attractive alternatives to these countries.

Introduction

The space race of the twentieth century was relatively simple: a two-superpower state-level competition between the US and the USSR to develop space technology that symbolized national power, economic might and global prestige. In the twenty-first century, the competition in space between the US and China is no longer simple.

Since its first manned mission in 2003, China's space program has accelerated dramatically. China completed the BeiDou System (BDS) satellite constellation in 2020, as well as its own Global Navigation Satellite System (GNSS), sent rovers to the far side of the Moon in 2019 and to Mars in 2021, and is assembling its own space station with completion scheduled in 2022. At the same time, countries with close ties to the US, such as India and the United Kingdom (UK), have their own stated space ambitions and agendas. In addition, private companies such as SpaceX, Virgin Galactic, and BlueOrigin are focused on outsourced contracts by the National Aeronautics and Space Administration (NASA) and/or the commercialization of space. Their Chinese brethren such as i-Space, OneSpace, and LinkSpace are also pursuing private-sector opportunities in space.

Such globalization and democratization of outer space activities in recent decades, coupled with technological advancement and few rules over outer space protocols, have complicated the geopolitical competition between the US and China. For example, how will the completion of BDS affect China's global influence? More specifically, will BDS shift the current power distribution between the US and China in the South China Sea—a crucial hot spot over which the two powers are competing—toward China? Will the thriving private sectors in the US and China alter the dynamics of geopolitical competition between the two countries by providing cutting-edge space technologies to their home country and henceforth excel in the global market? There are many critical questions and few answers. This study contributes toward answering such questions by focusing on the Belt and Road Initiative Spatial Information Corridor (BRI–SIC), China's most obvious geopolitical space-related activities, providing space-related services to the Belt and Road Initiative (BRI) members.

BRI was first mentioned by Chinese president Xi Jinping in his 2013 speech at Kazakhstan's Nazarbayev University.[1] It is primarily a project to secure China's economic growth, an imperative for the Chinese Communist Party (CCP) to stay in power.[2] In the name of an expansion of connectivity to benefit China as well as BRI member countries, China provides funding and services focused on critical infrastructure of the host countries including ports, airports, roads, railroads, highways, pipelines, and power generation facilities, without which the host countries cannot develop their economies or reduce poverty.[3]

Dependence on these projects translates to China potentially having a degree of leverage over the roughly 140 BRI member countries.[4]

With the targeted focus on providing infrastructure to host countries and the deployment of an almost irrationally large amount of funding and loans likely beyond hosts' capacities to repay,[5] some suspect that China also wants to directly control such key infrastructure assets for its own strategic purposes by burdening BRI countries with enormous debt.[6] The Hambantota Port in Sri Lanka, a part of the BRI project, is the prototypical example. As Sri Lanka was unable to service the loan, it ceded the right to control the port to a Chinese construction company for a period of 99 years.[7] Analyzing the BRI port projects, Daniel Russel, a former US State Department senior official, sees China weaponizing the BRI "by creating a Sino-centric ecosystem of trade, technology, finance and strategic strongpoints—undermining American influence and role as a security guarantor."[8]

Is BRI–SIC designed to benefit China's global military strategy due to the military-civil dual-use nature inherent to space-related activities and technologies? Is it a part of the alleged weaponization of the BRI to undermine American influence? The Indo-Pacific Defense Forum, a US military–related organization, expressed a clear concern with BRI–SIC. Emphasizing the heavy military involvement in China's space activities, its staff wrote that the "PRC [People's Republic of China] is often enriched at the expense of the host nations" and that the "aggressive push [of the BRI–SIC] is adding to growing international opposition to overall OBOR [i.e., the BRI] expansionism, given that the space sector has myriad security."[9]

Are these concerns legitimate? Should the US and its allies be concerned with China's global expansion of space-related activities under the BRI–SIC? Despite numerous research papers and reports on the BRI, a thorough analysis of space-related BRI projects has not been undertaken.[10] This study will close that gap by providing an unbiased risk-benefit analysis of such projects to deepen and extend our understanding of what the Chinese government intends to achieve from BRI–SIC.

Background and Rationale

Should the US and its allies be concerned with China's global expansion of its space-related activities in the name of BRI–SIC? To answer this question, a detailed and careful examination of each project is required, free of preconceived bias that might otherwise taint the analysis due to both the nature of space-related activities and how China deals with activities in outer space. These two factors are examined below to demonstrate the rationale of this study.

Nature of Space-Related Activities

Space-related activities are useful, growing, lucrative, and equivocal—and therefore unsettling.

Dual Military-Civil Use. Satellites—more specifically the data/signals they generate or the communication they transmit—are inherently dual-use between military and civil. According to Joan Johnson-Freese, as many as 95% of satellites are dual-use.[11] In June 2021, commercial satellite images identified 119 Chinese construction sites in desert locations that researchers believe are silos for intercontinental ballistic missiles,[12] underlining the difficulty of identifying how a satellite and/or its data are used. A commercial satellite can also be used for military purposes. Perhaps the use of GNSS is the most obvious dual use: while GNSS offers convenience to daily living by providing positioning, navigation, and timing (PNT) services, it was invented by the US military initially for its own use. Today, the GNSS provided by the United States is known as the Global Positioning System (GPS).

Using a satellite for both civil and military purposes is economical. Given limited budgets, "many countries, including China, France, and Japan, deliberately develop technology or establish organizations and operations for dual-use purposes."[13] A document released by the Japanese Space Development Strategy Headquarters （宇宙開発戦略本部） maintains the Military-Civil Dual Use Abroad section that explains how Germany, Italy, and France are using their satellites for dual purposes.[14] To the same end, while China asserts that its Yaogan (瑤感) satellite series is intended for civil remote sensing,[15] the US treats them all as reconnaissance satellites.[16] Likewise, even though China and Italy are cooperating on a satellite system for earthquake monitoring, an expert in the field questions China's intention behind that cooperation.[17]

Dependency on Space Activities. Modern lives have become more dependent on the far-reaching roles that satellites play in aviation navigation, precision agriculture, maritime security, satellite TV broadcasting, weather forecasting, earthquake monitoring, and natural disaster response. The more advanced society becomes, the more satellites will be in use, and the market for space--related business is expected to grow. Accordingly, current developing countries will at some point become important markets for satellites and satellite data–related businesses. One expert estimates that a billion people will access the internet through satellite constellations by 2029,[18] and constellations such as SpaceX's Starlink have proven valuable in providing broadband internet access during times of crisis as in Ukraine in 2022.

Aware of the rapidly growing global market, satellite-related service providers are acutely conscious of potential business opportunities in developing

countries. China and its satellite-related business vendors are positioned to permeate such markets due to the BRI projects supported host nations, which predominantly are developing countries.

Outer Space as an Extension of Cyberspace. "Satellites are computers in space connected to even more computers on the ground."[19] This succinct remark by Brian Weeden, an expert in space security, points to another critical aspect of space activities. Outer space is an extension of cyberspace and shares the same characteristics. A fundamental issue with satellite security, as with cyberspace, is that identifying attribution is difficult. For instance, the US weather network suffered a breach in 2014, and the National Oceanic and Atmospheric Administration confirmed that China was responsible. When reporting on the breach, the *Washington Post* noted that Chinese officials had denied repeated accusations and also referenced an expert who said that determining the origin of a cyberattack is difficult.[20] Such a situation makes determining an appropriate response challenging.

Disrupting a functioning satellite does not require physical damage to the target. Rather, penetrating and manipulating the satellite's computer system can disrupt its mission.[21] Derek Tournear, the director of the Space Development Agency (SDA), is reported to have said that the SDA is less concerned about missile strikes than it is about cyberattacks and intrusions into the supply chain.[22] Satellites can indeed be the target of hackers. "Hack-A-Sat" is an event sponsored by the US Air Force and US Space Force, where cybersecurity experts compete to access the computer system of a satellite to take over control and complete an assigned mission that differs from the original mission assigned to the satellite.[23] This event is a controlled manipulation of a satellite yet demonstrates the vulnerability thereof.

These traits of satellite security indicate that cybersecurity is a key criterion when examining the risks for a nation hosting BRI–SIC projects.

Few Regulations on Outer Space Activities. At the end of 2021, 4,852 satellites were in operation, with 2,944 belonging to the US and 499 to China.[24] In addition, SpaceX alone plans to deploy tens of thousands of small satellites into Low Earth Orbit (LEO) via Starlink.[25] Despite the vast number of satellites, the rapid increase in the number of space-related players (both countries and companies), and the dependence of daily lives and emergency responses on data from satellites, few treaties regulate activities in outer space universally. The 1967 Outer Space Treaty, ratified by 111 countries and signed but not ratified by an additional 89 countries,[26] is still the only major treaty that provides rules for outer space activities. As this treaty was agreed to as a result of an escalating nuclear arms race between the US and the USSR, it has a narrow

scope; it merely limits the use of outer space to peaceful purposes to ensure the arms race did not extend to outer space as well.

In May 2021, the world was on alert when it was unknown where debris from a Chinese rocket would hit the Earth. Despite such catastrophic potential, no rules or laws impose accountability on China, a reality that is problematic to say the least. However, while the US military realized the necessity of defining "what constitutes threatening, hostile or irresponsible behavior,"[27] Dr. Weeden suggests that US agencies are not pushing for new legally binding space rules because they do not want to be bound by them.[28] Consequently, as Christopher Newman, a space law and policy expert, said in 2019, "space players will continue to enjoy a degree of 'anarchy.'"[29] In this way, space-related activities are often seen as "anarchic.'[30] Such an image may well affect the image of BRI–SIC projects, as they are not regulated; one cannot easily discern what China is contemplating in the name of BRI–SIC.

The Prisoner's Dilemma. The characteristics discussed above—the military--civil dual-use nature of satellites, the increasing importance of outer space activities, the connection between outer space and cyberspace, and a lack of rules and accountability—lead active countries to address the so-called Prisoner's Dilemma. Under this hypothetical, the rational choice for both players in a two-player game is not to cooperate (i.e., defect) regardless of the other player's choice, even if both know that mutual cooperation maximizes the payoff as a whole.

Cooperation is difficult among players regarding outer space activities. First, no rules exist to enforce cooperation. Second, because outer space activities can impact national security, no country will risk being deceived. Rather, the choice is to deceive rather than to be deceived. Third, it is difficult to convince each party that its counterpart will cooperate given that lack of clarity of action due to the military-civil dual-use nature and the difficulty to identify attributions. Fourth, a player cannot be sure if it is interpreting the other players' activities correctly (for example, the divergent views over the Chinese Yaogan satellites).[31] Where deception is the rational choice for players, players distrust each other. Symbolically, Dean Cheng, an expert in Chinese military activities, said: "We'd have to assume that all satellites launched by China are now potential nuclear weapons carriers."[32]

If space-related activities are a case of the Prisoner's Dilemma, then activities in the name of the BRI–SIC may be a case in point: Regardless of China's assertions, one cannot know their actual actions. Absent trust, the only rational choice is to deceive.

Security Dilemma. As the Prisoner's Dilemma consolidates distrust among nations, this in turn leads to another dilemma: the Security Dilemma, a situation in which an actions to secure a state decrease its security by causing others' reactions. Whether or not a state feels secure depends on its threat perception. A perceived threat creates insecurity and results in increasing measures to counter that threat, typically by increasing armaments. An activity or condition is a threat to a state only where both capability and intention exist. In outer space, distinguishing whether a satellite or a space-related activity is a threat is difficult—often impossible—because the capability and intention of satellites or such activity is difficult to identify.

First, one cannot easily ascertain the player's intention behind a satellite's operation or a space activity because of the dual-use nature. Freese-Johnson states that "deciphering the motivations and intentions behind the development of dual use technology is speculation at best."[33] Second, the dual use nature of a satellite operation (or any space activity) obfuscates the military capability thereof. For example, technology to remove space debris by approaching other space objects can also be used to cripple satellites.[34] Here, misunderstanding and misinterpretation are natural outcomes. Reflecting the impossibility of understanding the true intent of outer space activity, General Mark Milley, Chairman of the Joint Chiefs of Staff in the US, said when interviewed by the Financial Times in 2020: "The first shots of a future war between great powers is likely to be in space and cyber."[35]

IMPLICATIONS (1)

All these characteristics of outer space activities indicate that, if one wants to correctly understand the intension of an activity in space, one must be careful and unbiased in analyzing its actual and potential usages. For example, commercial satellite images enhance military capability. Expansion of the BRI–SIC can create the perception that China is augmenting its military capabilities.

Belt and Road Initiative Spatial Information Corridor

China's attention to outer space is not new. During the Mao era in 1958, the importance of utilizing outer space was acknowledged and pursued as the "Two Bombs, One Satellite" project (两弹一星).[36] Nonetheless, China's remarkable advancement in outer space technologies and exploration became possible only after China's rapid advance in technology and its economy after Deng Xiaoping introduced a market economy to China and joining the World Trade Organization in 2001.[37] As China is catching up with the US economically, militarily, and technologically, China has become more focused on advancing its space capabil-

ity for three core reasons. First, understanding that the US superiority in military strength derives in part from space technology such as precision-targeted missiles and intelligence and surveillance activities in space,[38] China understood that having its own space capability was critical for its national security. Second, despite this criticality, China had to develop its space capability on its own. Since the so-called Wolf Amendment took effect in 2011, NASA is prohibited from cooperating with China,[39] and various Chinese aerospace-related state-owned enterprises (SOEs) are listed in the International Traffic of Arms Regulations, thereby preventing US companies from trading with these entities.[40] Third, as explained below, the Chinese Communist Party understands the broad utility of space-related advancement for CCP to remain in power.

China's Goal of Becoming a Great Power in Space. Perhaps the most straightforward and comprehensive description of China's interest in space is in the "2016 White Paper on China's Space Activities." It defines China's outer space goal as "to build China into a space power in all respects (全面建成航天强国)" while acknowledging that "space activities . . . exert enormous impact on other fields" and that the "Chinese government takes the space industry as an important part of the nation's overall development strategy." Developing space activities is necessary for "economic, scientific and technological development, national security and social progress." Importantly, promoting space activities is identified as China's historical mission. The Paper states that building China into a space power supports "the realization of the Chinese Dream of the renewal of the Chinese Nation."[41] The 2016 White Paper then lists the major tasks for the next five years, including space transport systems, space infrastructure that focuses on communication, remote sensing and PNT satellite systems, manned spaceflight, deep space exploration, experiments in new space technologies, and space application.

The 2016 White Paper highlights how rapid, peaceful, and beneficial China's space development had been and will be. However, in reality China has also been increasing its military capability in space, alarming the US and its allies. For example, the US Defense Intelligence Agency published "Challenges to Security in Space" in 2019, which features China as a primary threat in space to the US.[42] Given the focus on BRI–SIC in this study, the military aspect of China's space development is not examined here.

China's intention to build out space-related civil capability is articulated in the "National Medium-to Long-Term Civilian Space Infrastructure Development Plan (2015–2025)" released in 2015 by the PRC National Development and Reform Commission.[43] The 2015 Space Infrastructure Development Plan stresses the criticality of space as a source of data and information: "Civilian

space infrastructure is both strategic infrastructure for modern informatized [信息化],, intelligentized [智能化] society and an important method for propelling scientific development, transforming the mode of economic development, and thus achieving innovation-driven development, [and] is also an important support for national security." Recognizing that "every field and every sector is placing wider and more urgent demands on the building of an autonomous and open civilian space infrastructure," the plan explains how remote sensing, communication, and PNT satellites support various activities.

China sees data as "a critical production factor in the new era and a basic strategic resource" (appearing in the "14th 5-Year Big Data Industry Development Plan").[44] And China sees outer space as a source to obtain data. The "14th 5-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035" released in March 2021 promotes China's innovation-driven and digitalization-based development and insists: "We will build high-speed, ubiquitous, integrated and interconnected, safe, and efficient information infrastructure that integrates space and earth (天地一体) and enhance data perception, transmission, storage, and computing capabilities."[45]

Belt and Road Initiative Spatial Information Corridor. Initially translated as "One Belt, One Road," the Belt and Road Initiative is President Xi Jinping's grand strategy to maintain China's economic growth, which represents the main source of CCP's ruling legitimacy. Commencing in 2013, BRI is a multicontinent initiative designed to enhance connectivity between China and countries in Asia, Africa, Europe, and Latin America by implementing projects that are often funded by China. President Xi started BRI with the Silk Road Economic Belt through Eurasia, and a month later he proposed the 21st Century Maritime Silk Road that extends from China to Africa and Mediterranean Europe.[46] The Digital Silk Road was added in 2015,[47] as was the Health Silk Road in 2020.[48]

In 2016, China's State Administration for Science, Technology, and Industry for National Defense (SASTIND) under the Ministry of Industry and Information Technology (MIIT) released the "Guiding Opinion on the Belt and Road Initiative Spatial Information Corridor" based on the above-mentioned "National Medium-to Long-Term Civilian Space Infrastructure Development Plan (2015–2025). "[49] This Guiding Opinion announced that China would include a space-related corridor in the BRI and describes the BRI–SIC as a mechanism to create a China-centered global framework to facilitate marketization of Chinese space technologies and their applications and the internationalization of China's space industry. The main goal is to promote Chinese economic growth through the expansion of China's space-related

activities based on the resources generated from its communication, navigation, and remote sensing satellites.

To implement the BRI–SIC, the Guiding Opinion provides core principles. First and foremost, BRI–SIC projects should be guided by President Xi's priority of promoting military-civilian integration and win-win international cooperation along with the Belt and Road Initiative. Second, the Guiding Opinion refers to specific guidelines: BRI–SIC projects should be inclusive and extensive, government-guided, demand-oriented, mutually beneficial among the all stakeholders, and application-focused. Third, the Guiding Opinion notes that, while the government supervises the planning and coordination of projects, in practice market forces and commercial enterprise will drive technology innovation and resource allocation for the BRI–SIC. Based on these principles, BRI–SIC projects aim to extensively market space technologies globally to assist international cooperation and furtherance of BRI.

The Guiding Opinion designates the BRI–SIC to enhance the spatial information generation and application capability for the BRI by, for example, accelerating the time required for satellite system construction and space-earth information network coordination; promoting supplies and procurements of China-made spatial data and services; establishing data centers and application service platforms; and accelerating commercialization of spatial information sharing service networks. In addition, the BRI–SIC is a part of the "GO OUT" strategy(走出去战略) created in 1999 to promote Chinese foreign investments and expand China's foreign markets and its brand[50] such as slowly expanding its power in Africa, "one TV set at a time."[51] The Chinese government sees BRI–SIC as useful to accelerate the development of all BRI projects such as port and highway construction because satellite services provide positioning, navigation, and timing services and satellite images that facilitate such construction.

As an example of BRI–SIC's alignment with the GO OUT strategy, in 2018 the China Communication Technology Co. Lt. (CCT) acquired G Telecoms, the third largest telecom operator in the Philippines.[52] In a report by the China Daily (中国日報), Yao Chuanbin, CCT's board secretary and investment director, said, "The Belt and Road Initiative has brought us great opportunities and we will push forward with our strategy in coordination with the national plan." CCT's president, Wu Guangsheng, also said, "In the past, we could cooperate only with local (telecom) carriers in foreign countries by selling our equipment to them. The big step now means we can operate independently, be it launching our own satellites or providing data-related services."[53] CCT is dealing with the Pilipino Navy and Coast Guard.[54]

While the Guiding Opinion does not clearly delineate the scope of the BRI–SIC, it does provide a (nonexhaustive) list of the use China's space resources as part of it. These include building emergency service platforms; enhancing maritime security along with the Maritime Silk Road; promoting cooperation around transboundary rivers; exporting satellites and satellite-related products, operational services, and application systems to establish related technical standards; expanding the space information service market particularly along the Maritime Silk Road; and constructing a "spatial information+" industrial ecosystem.

The BeiDou Navigation Satellite System **(北斗卫星导航系统).** The BDS is the Chinese global navigation satellite system for both military and civilian use operated by the China National Space Administration (CNSA),[55] and the last satellite to complete the constellation was successfully launched on June 23, 2020. BDS, with 35 satellites, is the largest GNSS constellation to date.[56] In CNSA's official document, the goal of BDS development is "to meet the needs of the country's national security as well as economic and social development, and providing continuous, stable and reliable services for global users."[57] The BDS has increased China's capability in three ways: militarily, economically, and geopolitically.

First, the BDS materially enhanced China's national security, which is the primary goal. China had pursued its own GNSS since 1994 to avoid reliance on GPS, the GNSS of the US, and to internally control critical parts of its national security.[58] For example, when Chinese missiles were not directed as intended during the 1996 Taiwan Strait Crisis, a Chinese military official was reported to have said that the failure was due to the intentional failure of GPS navigation.[59] A corollary of China's own GNSS is a reduced dependence on the US and a substantial reduction in the relative power of the US, the US can no long coerce China by leveraging the use of its GPS. According to a Taiwanese expert, BDS allows the People's Liberation Army (PLA) to operate nighttime air squadrons in areas key to the US Navy accessing the South China Sea and strengthen the capabilities of its early-warning planes in those areas."[60]

Second, China uses the BDS as a critical vehicle to develop its economy. For example, the "14th 5-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035" describes the BeiDou system as one of the "emerging industries" that increases the "core competitiveness" of China's manufacturing.[61] It states: "We will promote the application of the BeiDou system and the high-quality development of the BeiDou industry." Heath Sloan, the Yenching Scholar at Peking University, notes that "BeiDou is intrinsically linked to 5G and IoT . . . the major component of 'China's Digital Silk Road,' [which for China] a blueprint to become a global leader in advanced technologies."[62]

Therefore, it is not surprising that BDS is deeply embedded into BRI. In 2018, even before the completion of the constellation, the *New York Times* described BDS as a core component of BRI.[63] Just a year after BDS started domestic commercial application in 2011, it went beyond China's border into the Asia-Pacific region.[64] In China alone, "more than 7 million commercial vehicles, about 36,300 postal and delivery vehicles, and 350 aircraft" had been equipped with BDS by May 2020.[65] This implies a significant potential market for BDS equipment and transportation in BRI member countries as their economies grow. This is exaggerated by the proven benefits of using BDS. The 2021 White Paper on the Development of China's Satellite Navigation and Location Services Industry released by the China Satellite Navigation and Positioning Association states that, by the end of 2020, the number of major accidents dropped 93% and the mortality rate dropped 86%.[66] To date, numerous BDS-related projects in the name of the BRI–SIC have launched in BRI member countries or signed with Chinese companies, meeting the demands of developing countries. By 2019, 120 members had imported BDS-related components.[67]

Furthermore, BDS has already excelled in some GNSS-related service markets. According to Nikkei in 2019, in 85% of world capitals (165 out of 195 countries), BDS satellites are more visible than GPS satellites. The report details how BDS services are welcomed in Ethiopia and help small business owners by sending signals to cheaper Chinese smart phones in the country.[68] The Nikkei article focuses on BDS service global expansion, highlights the rising influence of BDS-related industries in the world, and reports on how major global semiconductor manufacturers, such as QUALCOMM and ST Microelectronics, are rushing to produce BDS-compatible devices.[69] It is only the American continents and West Africa where GPS satellites surpass visible BDS satellites.

Third, the provision of BDS services benefits China by increasing its global geopolitical influence. As early as 2013, the *South China Morning Post* clearly illuminated the intention embedded in China's promotion of BDS to Thailand:[70] China seeks to eclipse the influence of the US in Asia by using BDS in three ways. First, China sells BDS-equipped products and will attempt to sell BDS-equipped weapons, particularly to countries relatively close to China, such as Laos and Cambodia, as it has done with Pakistan.[71] According to Ian Storey, a Southeast Asia geopolitics expert, Thailand is "the first Southeast Asian country to buy Chinese tanks, submarines and a large amphibious landing ship . . . [which] may inspire other countries to follow suit."[72] National defense of the BDS-equipped weapon user countries is then reliant on China, particularly when GPS is not reliable to control their weapons. The consequence of China exerting influence is more critical than the use of BDS in a civil context (such as traffic navigation).

What's more, China collaborates with Russia. Some experts see the cooperation between BDS and GLONASS, Russia's GNSS, as intended to expand their coverage and accuracy, which "might erode GPS's advantage globally"[73] and "replace GPS as the leading global navigation system."[74] Similarly, Dana A. Goward, the president of the Resilient Navigation and Timing Foundation, is concerned with BDS/GLONASS cooperation: GPS users may switch to its network because China and Russia disrupt GPS too frequently to use it stably.[75]

China provides BDS to countries who cannot use GPS, resulting in increased dependence on China. One example is Iran. The US "had prohibited Iran's access to high-precision services, but with the transfer of BDS technology from China, the country can now enjoy such services and develop its navigation technology."[76] Such an offer by China cannot but strengthen the relationship between China and Iran. Countries that have strained relationships with the US, such as Venezuela and Cuba, may well pursue the same path as Iran and thereby reduce the leverage that the US has through provision of GPS PNT services. Noting the completing benefits of the BDS system as a part of "China's long-term strategy in decoupling itself from foreign technology in matters of national security," Sloane said in 2020 that "the world may soon be bifurcated into GPS and BDS."[77]

Meeting Demand. The BRI–SIC is not simply a matter of the Chinese government driving projects that promote China's economic growth or the Chinese space industry pushing projects to spur economic profit. It is also pulled along by demand from the BRI member countries, particularly due to the utilities that satellite-related services can provide for natural disasters and their own economic growth.

First, Asia and Africa, the primary regions of BRI, suffered 68% of global fatalities by natural disaster in 2019.[78] Satellite data can help prevent or at least mitigate the consequences of such problems. For example, meteorological satellites allow forecasting and early preparation; remote sensing satellites monitor volcanic activity; and communication satellites are a backup resource when landline communication is disrupted, particularly in archipelago nations such as Indonesia and the Philippines and mountainous countries such as Laos. Recognizing the critical importance of access to satellite data to respond to a natural disaster, Japan, the US, the United Nations, and the Asia Pacific Regional Space Agency Forum (APRSAF), among others, provide such access, as does China. But China leverages its outsized national budget to provide access at subsidized pricing or even at no cost. For example, Mozambique, a BRI member prone to natural disaster, was extremely grateful for China's donation of an earth observation satellite to the country.[79]

Second, demand for the BRI–SIC is driven by the BRI members' economic growth, particularly in Southeast Asia, that has seen an average 5% GDP growth rate since 2015 and an expectation to revert to that level in 2021 post–COVID pandemic. The high GDP growth rate has been accompanied by an increase in construction output in the region, though this estimation was hampered by the economic downturn during the global pandemic. Satellite services aid construction, such as earth observation data, satellite communication and PNT services. BDS was famously used to build the National Kuwait Bank building in 2012.[80]

Aside from construction, as individuals become wealthier, demand naturally increases for GNSS with increased cell phone usage, air travel, navigation services, efficient financial operations, and satellite TV. A report on the satellite data service market notes that the Asia-Pacific is expected to emerge as the fastest growing regional market, reaching $36.9 billion annually by 2027.[81] This is corroborated by other market research that similarly predicts that, between 2018 and 2026, the Asia-Pacific will be the fastest growing GNSS chip market; the largest in absolute terms will remain North America.[82]

In such promising markets, Chinese vendors of BDS-related products are permeating the BRI markets due to two elements. First, BDS has more coverage in these countries. Second, Chinese GNSS receivers are cheaper, and given that there are more signals from the BDS, their positioning/navigation accuracy is sufficient for business. The Nikkei article quoted above provides additional details: Most of the population in Addis Ababa does not have a home address and thus GNSS navigation is critical for delivery services; Ms. Koga's business increased sevenfold in three years thanks to cell phone mapping apps delivered predominantly on affordable Chinese-manufactured cell phones.[83]

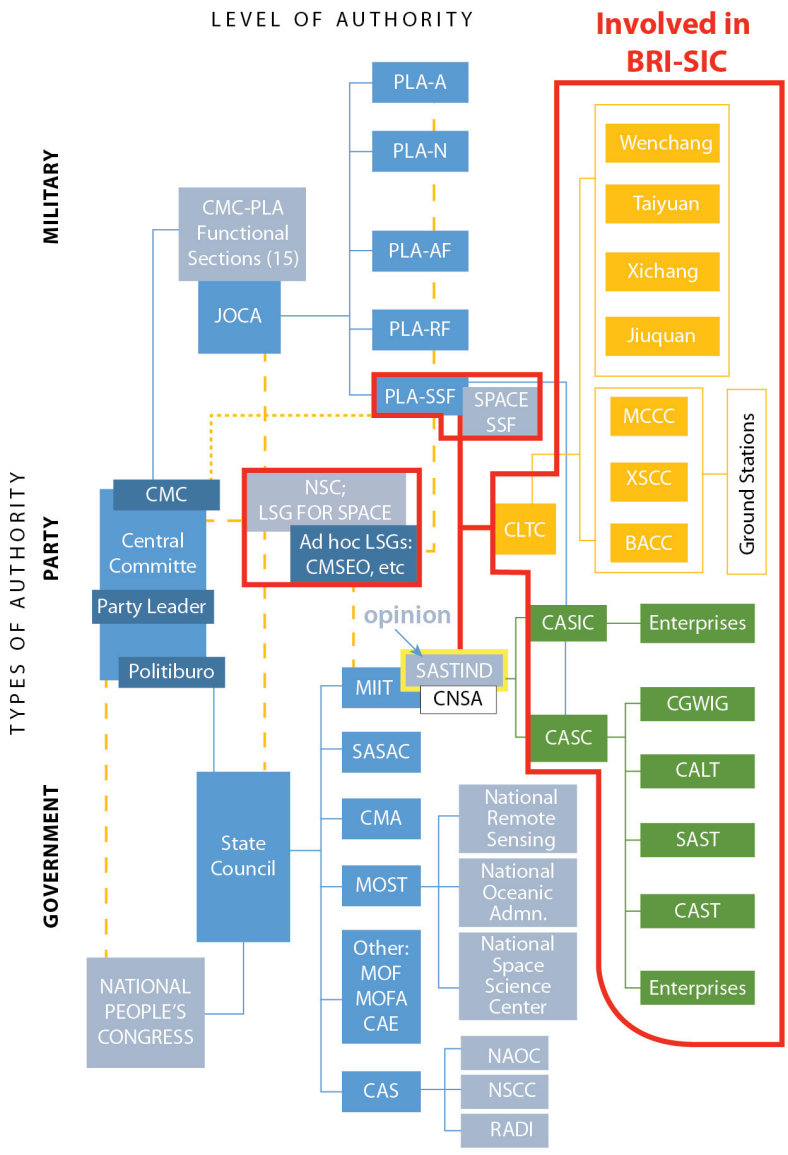
Military Involvement in the BRI–SIC. At its inception, the BRI–SIC was to be carried out through military-civil fusion (MCF, 軍民融合) as detailed in the Guiding Opinion. MCF, one of China's strategies to accelerate its economic growth and military modernization, took shape after the Central Commission for Integrated Military Civilian Development （中央军民融合发展委员会） was created in 2017. MCF then officially became a national strategy.[84] The BRI–SIC was, in this way, meant to involve the People's Liberation Army.

Because of the military-civil dual nature of space-related assets and activities, most commercial satellite manufacturing companies deal with the military and civil sectors, such as Boeing in the US and Mitsubishi Heavy Industries in Japan. But China's MCF is different. State-owned enterprises (SOEs) such as China Aerospace Science and Technology Corporation (CASC: 中国航天科技集团有限公司) and the China Aerospace Science, Technology and Industry Corporation (CASIC: 中国航天科工集团有限公司) are a part of

the government and continue to lead the manufacture, launch capabilities, and operation of satellites, particularly for BRI–SIC projects without considering balance of payments. China Great Wall Industry Corporation (CGWIC: 中国长城工业集团有限公司), a subsidiary of CASC, is "China's only space company authorized by the government to conduct business internationally."[85]

As illustrated by figure 1, CASC and CASIC are both under MIIT, which collaborates with the Strategic Support Force (PLA-SSF), a part of the PLA, to manage China Satellite Launch and Tracking Control General (CLTC). CLTC administers all ground stations and launch sites in China. The China National Space Agency under SASTIND, a part of the MIIT, is responsible for the national space programs.[86] The part circled in red in figure 1 (added by the author of this study) is involved in the BRI–SIC. The organizations in green are SOEs, and those in yellow are parts of the PLA.

Integration of the military and civilian sectors is not limited to SOE operations. Perhaps more relevant to BRI–SIC, MCF is ingrained in institutional and individual attitude, presumably originating from their genuine nationalism and/or possibly compelled by various laws such as the 2017 National Intelligence Law that mandates "all organizations and citizens will support, assist and cooperate with national intelligence efforts."[87] For example, the Belt and Road Initiative Spatial Information Corridor Haishi Research Institute (一带一路空间信息走廊海丝研究院), a think tank that undertakes research for satellite application along the Maritime Silk Road in Fujian, was established "to fully implement General Secretary Xi Jinping's important thoughts on strengthening the military and developing military-civil integration as well as his strategy to build a strong nation and the military."[88] As for individuals, many private sector business leaders such as Jack Ma, the founder of Alibaba, and Ma Huateng, a founder of Tencent, are members of CCP and, as such, support strengthening the Chinese military.[89] One of the most vocal business leaders in supporting CCP's military is Lei Jun（雷军）, the founder of the Chinese tech giant Xiaomi. He specifically mentioned MCF in the context of space: "The commercial space sector, featuring innovation, high technology and military-civil fusion, is the path the nation must take to shift from a big space country to a strong one."[90]



"Image courtesy of Marco Aliberti, European Space Policy Institute"

Figure 1. China's space-related governmental organization chart

IMPLICATIONS (2)

BRI–SIC is loaded with both the Chinese government's ambition to expand China's market and develop its technology with the PLA's engagement. How much does BRI–SIC really involve and benefit the PLA? Due to the dual-use nature of space-related activities, the answer requires a careful examination of each project.

BRI–SIC Risk-Benefit Assessment

Methodology

This study is meant to extend and deepen the understanding of the actual or potential impacts of the BRI on host countries and what such impacts mean to the US and its allies. It is not to verify existing theories or to propose a new theory. Therefore, this study focuses on a precise project analysis by employing appropriate criteria and procedures in assessing the risks and benefits of each project to the host country. The findings will address the question posed at the outset: *Should the US and its allies be concerned with China's global expansion of its space-related activities under the BRI–SIC given that the PLA is involved in such activities?*

Preliminary Research. To contextualize the BRI–SIC, this study starts with intensive and extensive research on (1) China's political, economic, and military activities; (2) China's foreign relations and domestic issues; (3) the US-China geopolitical competition in Asia and in the world; and (4) China's space-related activities domestically and abroad, including those related to space technologies and cybersecurity.

Definitions. Prior to commencing the risk-benefit assessment of the BRI–SIC projects, a clear delineation is required because BRI itself is somewhat vague and wide-ranging. The 2020 report to Congress by the US-China Economic and Security Review Commission (USCC) describes the BRI as having "no membership protocols or formal rules but is based on informal agreements and a network of bilateral deals with China as the hub and other countries as the spoke."[91] Based on his extensive BRI research, Jonathan Hillman confirms the report's description: "The BRI was officially launched in 2013, but projects started years earlier are often counted. . . . The BRI's loose, ever-expanding nature, and a lack of project transparency, have led many observers to exaggerate its size."[92] As an example of the BRI–SIC, a member of the Expert Committee of One Belt One Road Hundred People Forum counted all Chinese manufacturing of foreign satellites since 2008 as BRI–SIC projects.[93]

Delineating the scope of the BRI–SIC is not easy. The above-mentioned presentation by Jiang Hui, the director of the International Cooperation Department at CNSA, had a presentation at the United Nations Committee on the Peaceful Use of Outer Space in 2018. In it, he highlights sharing remote sensing data with the BRI members as BRI–SIC core activities. But he includes within the scope of the BRI–SIC deep space exploration, space debris removal efforts, space law making cooperation, and technology transfer to the member states,[94] some of which have not yet been initiated.

Based on numerous preceding examinations of the BRI, this project defines a BRI–SIC project as a space-related or satellite data–based bilateral or multilateral project in which China and BRI member(s) are cooperating as either equal partners or as a provider-client partnership, whether completed, actual, or planned. The specific scope of the BRI–SIC is further detailed below.

Data Collection. Having undertaken background research and defining the scope of BRI–SIC projects, this study identifies the BRI–SIC projects within that defined scope. Project data was gathered through deskwork and research from resources in both English Chinese and Japanese.

Primary Sources

- Official documents on websites of governmental organizations in relevant countries such as China, the US, Japan, the European Union, and BRI host countries. The main organizations in charge of space activities include CNAS, NASA, the Japan Aerospace Exploration Agency (JAXA), and the Europe Space Agency. The BDS constellation has its own official website (北斗卫星导航系统，en.beidou.gov.cn), as does GPS (gps.gov).
- Documents on websites of international institutions such as the Asia Pacific Space Cooperation Organization (APSCO), APRSAF, and the United Nations Office for Outer Space Affairs.
- Documents on websites of Chinese space-related companies such as CASC and its subsidiary CGWIC.
- Records of USCC hearings to understand how US policy makers shape their views of China's space activities from various perspectives (uscc.gov).
- Interview records from interviews conducted by the author of this study.
- Conference speeches and discussions recorded by the author of this study.
- Newspaper articles related to the BRI–SIC written by "reporters who witnessed an event or who quote people who did"[95] (including but not limited to Xinhua, Sina.com.cn, Belt and Road News, CCTV, Global Times, people.cn, Space News, GPS World, GPS Daily, Inside GNSS,

Space in Africa, the Belt and Road Initiative, and other BRI member countries local news media).

- General news and media reports reporting events and comments (including but not limited to the *New York Times*, Reuters, the *Washington Post*, the *Wall Street Journal*, *Asahi, Nikkei*, *The Economist*, *Financial Times*, *The Guardian*, *The Diplomat*, *Foreign Policy*, *Foreign Affairs*, *Defense One*, and similar publications).

Secondary Sources

- Academic research papers, particularly those on *Space Policy, Astropolitics* and *International Security.*
- Books relevant to this study.
- Websites with information on space activity and national security (such as Gunter.com, Satbeams.com, Spaceflight.com, and Globalsecurity.org).
- Reports released by various research institutions on relevant matters such as the BRI, China's space activities, the US-China relationship, and space technology such as the China Aerospace Studies Institute (CASI) Air Force University, Secure World Foundation, the Center for Strategic and International Studies (CSIS), and the Asia Society.

Interviews. This study conducted approximately 40 interviews via Zoom, phone, or email to deepen and confirm research investigation. The experts includes journalists in BRI member countries, staff members in space-related national organizations such as JAXA and NASA, experts on China's space activities, scholars of international relations and outer space, cybersecurity experts, satellite operations experts, and space-related industry experts. The main areas of inquiry included:

- China's space-related activities, goals, weaknesses, and strengths.
- Space activities by other countries such as Japan, India, and other Asian and African countries.
- China's BRI projects.
- Space-related technologies.
- The relationship between space technologies and cyber technologies and how cybersecurity is critical for security of space assets.
- China's space-related activities in BRI host countries.

Risk Assessment—Literature Review. This study assesses the potential risks and benefits of BRI–SIC projects. While the benefits are usually clearly stated

and even sometimes advertised, the risks are not as obvious. As such, this study refers to the following expert document for the risk assessment.

- "Security Threats Against Space Missions" ("Green Book") published in 2015 by the Consultative Committee for Space Data Systems (CCSDS).[96] The Green Book provides a threat analysis of five types of satellites, including communication, earth observation, and navigation satellites, which are relevant to this study. In practice, the *Green Book* details applicable threats, their impact, the probability of risk (level 1 to 5), and security mechanisms to counter such threats for each satellite type.
- "Cybersecurity Risk Assessment for Space Systems" written by team members from the Department of Defense & Space, Honeywell Aerospace, published in *IEEE Explore* in 2019.[97] This article asserts: "Anti-satellite actions are a part of standard military doctrine among multiple nation-states. So the base likelihood of an attack is a certainty—high-capability attackers will attack satellites." Further, it says: "It is necessary to change the risk assessment focus from what attackers could do given their capabilities, to a worst-case assumption of what an attacker could do given the satellite's capabilities." The satellite safety analysis process should be the same to that for commercial aircraft "where the goal is to be able to *state that any harmful event that could occur will occur unless there is verification and assurance that it won't occur*" (italics added).
- "Cyber Risk Scenarios, the Financial System, and Systemic Risk Assessment," a report published by the Carnegie Peace Endowment in 2019.[98] Because cyberattack is more likely threat to space-related activities than physical ones, this System Risk Assessment report extensively incorporates a cyberattack assessment and is relevant to this study. According to this report, nation-states "monitor other nation's economies for espionage, conduct cyber-attacks in rare cases." The frequency of such activities are described as "Espionage—common; destruction—very rare." This study references this analysis as the "Report."
- "Guidelines for Risk Management" ("Guidelines") released by NASA in 2014.[99] This study employs the definitions of "risk" and "risk assessment" presented in these "Guidelines." The "Guidelines" also provide a risk consequence criteria for space missions, helping this study to appropriately evaluate the ranking as the most serious among various potential damage and/or losses depending on the asset type.
- "Introduction to Cybersecurity for Commercial Satellite Operations (Draft NISTIR 8270)" ("Introduction") released by the National Institute of Stan-

dards and Technology (NIST), US Department of Commerce, in 2021.[100] This source is relevant for this study as it provides insight into the vulnerabilities of commercial satellites and ways to mitigate such.

- "Threat Modeling and Countermeasures of Continuously Operating Reference Stations Network Backbone to Improve Precise Positioning Service Security," an academic article published in 2018.[101] This article is valuable in understanding the mechanisms of cyberattacks on GNSS systems, particularly on continuously operating reference station (CORS) networks and the global diversity thereof with case studies.
- "Satellite Hacking: A Guide for the Perplexed" is another academic research paper, published in 2012,[102] that details how a satellite can be hacked and the historical records of satellite hacking.

Limitations. This study faced some challenges. The main limitation was a lack of detailed information about many of the BRI–SIC projects. While finding project names or news on projects was relatively straightforward, sourcing specific details for each project was difficult. That being said, information about projects related to satellite launch, manufacture, and operation are public and easily observed, partly because they are highly visible and large in scale. In addition, communication satellites must be registered to secure a slot and frequency bandwidth from the International Telecommunication Union (ITU), and owners of satellites must disclose all relevant information. Meanwhile, projects other than satellite operation–related, such as the sharing/processing/applying of Chinese satellite data or BDS application projects, have little information, particularly regarding the source of funding and identities of vendors. The following expands on the data collection challenges this study faced:

- *Paucity of project detail in Chinese news reports or Chinese government's official websites*. For example, according to news reports and official documents, the Guanxi–Zhuang Autonomous Region government has launched many space-related data-application projects with ASEAN, including the construction of a BDS data application center. News references are found, but with few details, either in Chinese or English.
- *Paucity of project details on the contractor websites, particularly those that are a global business*. For example, *China Daily* reported that CCT acquired the third-largest telecommunication company in the Philippines, iGSat. But this acquisition is not mentioned on CCT's website in either Chinese or English. Upon my request, CCT sent a PDF flyer with a brief description and pictures of iGSat activities but did not provide details of the company's business. This study has reached out to numerous Chi-

nese vendors, including their US and Japanese branches, to request product lists and global business details, but none responded.

- *Paucity of English local news about BRI–SIC projects*. Using the example above, even in the Philippines, where English is widely used, no information exists in the English-language news media about CCT's acquisition of iGSat or about iGSat itself despite being the third-largest telecom company in the country. Similarly, Chinese newspapers and government websites mention China's BRI–SIC space-related projects in Cambodia, but there are no local news reports in English. A journalist in Cambodia, responding to my inquiry, states that he had not heard anything of it.[103]
- *Travel-related restrictions*. Fieldwork may have assisted to fill the gap between the lack of detail in news reports or official announcement, but due to the travel restrictions since early 2020, this has not been possible.

Setting Answerable Questions

Should the US and its allies be concerned with China's global expansion of its space-related activities in the name of BRI–SIC? This study focuses on the following three concerns revealed in the Indo-Pacific Defense Forum article:[104] Does China want to dominate outer space via the BRI–SIC? Is the BRI–SIC actually intended for China to strengthen its terrestrial national security? And do BRI–SIC projects pose risks on the host countries more than providing benefits? Based on its interest, this study turns these concerns into three quantitative questions (the "Three Questions of Concern"):

Q1: Do most BRI–SIC projects increase China's spacefaring capability?

Q2: Are most of the projects useful for China to strengthen its national security?

Q3: Do most BRI–SIC projects risk the national security of the host countries rather than provide benefits to them?

Risk-Benefit Assessment

To examine these questions while evaluating BRI–SIC in a fair manner to identify nature of each project, this study conducts a risk-benefit assessment of each project with the following steps:

Data Collection:	Identify observable BIR-SIC projects and investigate the details of each.
Data Processing:	Categorization of data into project types. An alyze the benefits and risks each *project type*

	has on host countries. Conduct a risk-benefit assessment of *each project* to pro duce data.
Information Delivery:	Answer the Three Questions of Concern based on the data processed to provide in sight into the primary question.
Findings:	Interpret the results of the assessment to characterize the BRI–SIC. Provide implica tions to assist decision-making.

Identifying Observable BRI–SIC Projects. This study identified 108 projects in the BRI framework that involve 34 individual member countries, three regional organizations, and an international organization, APSCO, in addition to BRI itself. Because the BRI is amorphous, this study delineated its scope as follows.

Projects included:

- Any space-related project that China provides to BRI member countries with or without specific mention of the BRI–SIC, including those prior to 2013 when the BRI was first declared by President Xi.
- Any project completed, in progress, on hold, planned, announced by the Chinese government, cancelled, and/or failed. The list is inclusive so as to examine what China can or could have done by providing these projects, thereby being suggestive of the goal of the BRI–SIC.

Projects not included:

- Deep space exploration projects because their actual threats and benefits to the BRI members are uncertain.
- Military-related projects because the "Silk Road Spirit" is defined as "peace and cooperation, openness and inclusiveness, mutual learning and mutual benefit."[105] This study regards any project that uses BDS systems as weapons is not in line with the BRI and excludes projects of that type from this study's examination.

While the author of this study is confident that the resulting project list is complete, it may well omit some projects that are not observable. Nonetheless, given the scope of projects observed, this study will provide material insight to the question: Should the US and its allies be concerned about BRI–SIC? and deepen the understanding of what China seeks to accomplish with the BRI and more specifically with the BRI–SIC.

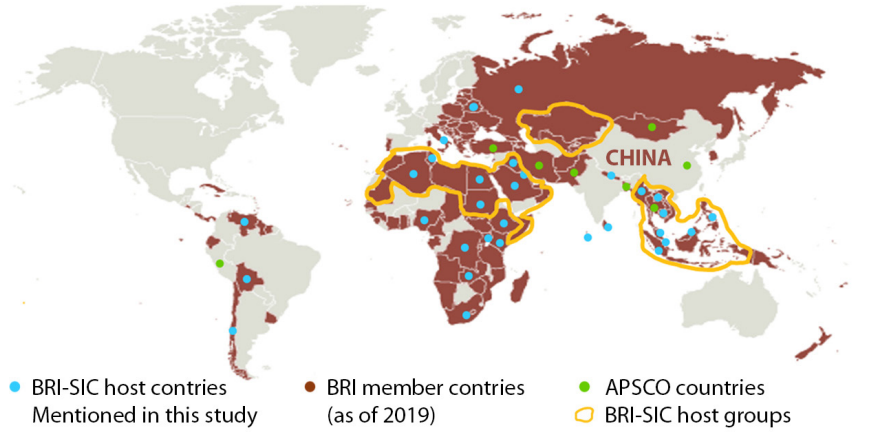
Once projects were observed, this study carefully collected information about each project to the extent available and seeks to identify the following items for each project: type of project; host country; important year such as the year of contract, satellite launched, or project reported; Chinese financial involvement; Chinese entities/vendors involved and/or contractor(s), along with important notes with a focus on national security–related aspects.

This study identified and observed 108 projects that were categorized into nine project types as summarized in table 1 (with the number of projects within that project type in parenthesis). As the type of each project is not always easily delineated and may touch on more than one category and is included in more than one category, the total exceeds 108.

Table 1. The nine BRI–SIC project types

Project type	
GSC (9)	Ground station (GS) construction by China and cooperation with China
SAT (24)	China provides a satellite (21 IOD projects), which the host country operates it alone or in cooperation with China. This category includes two "satellite launch only" projects (Pakistan and Saudi Arabia) and a project that China supports the host country's satellite manufacturing (Egypt).
COS (5)	Sharing/using China's communication satellite(s)
BDC (11)	Using China's CORS network for BDS/GNSS reception, including monitoring/remote tracking stations
BDA (27)	BDS applications for civil use, such as transportation, navigation, and agriculture. Some types of BDS business exhibitions and demonstrations are included in this category.
DTB (11)	Involving Chinese satellite data processing/application businesses, including BDS-related, with host countries
DTS (11)	China sharing its satellite-related data/information primarily for nonprofit purpose (BDS-related included)
TER (22)	China providing trainings, education and research-collaboration (BDS-related included)

Geographically, the projects span Asia, the Middle East, Africa, Europe, and Latin America, as illustrated in figure 2 below.[106]



Note: Up to April 2019. Source: http://www.yidaiyilu.gov.cn"

Figure 2. BRI–SIC project host countries

Possible Risk Identification of the BRI–SIC. Obviously, conducting a risk--benefit analysis requires an identification of the actual and potential benefits and risks. While the benefits are predominantly the same as the stated goal of a project, the risks are typically not stated. First, in examining the potential risks of BRI–SIC projects, this study employs NIST's definition of "risk" as being a "measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of: (i) the adverse impacts that would arise if the circumstance or event occurs; and (ii) the likelihood of occurrence."[107] Second, this study relies mainly on the literature listed above and, in particular, NIST's "Green Book."

Because space-related services use computer systems and/or data and information generated from them, damage to such services is more likely to be caused through the computer systems that facilitate them than other methods such as physical attack. Therefore, this study focuses on two primary risks of hosting a BRI–SIC project: the possibility of unauthorized data/information sharing by Chinese service providers, and the possibility of service disruptions or discontinuations via computer system by Chinese service providers.[108] This study examines only the risks inherent in space-related services and does not include the risk of the so-called debt trap, because the main inquiry is the nature of space-related activities.

Unauthorized data sharing

If a project uses a Chinese computer system, China has an advantage in gaining access to that system. And even if a computer system is not made by a Chinese manufacturer, China may still gain unauthorized access, although one would expect easier access where the system vendor is Chinese. If data can be commercially or strategically valuable for China, there is a possibility that the vendor can share the information without permission from the client.[109] According to the CCT, a Chinese telecommunication company, the Filipino navy uses a satellite communication system it provides.[110] If a conflict arises between China and the Philippines over the South China Sea, whether a physical or legal dispute, the Chinese government may leverage CCT to eavesdrop on the communication of the Filipino navy.

Disruption/discontinuation of service

Likewise, if a project uses a Chinese computer system, China can disrupt/discontinue services that the vendor provides to the client. It is expected that such disruption would occur only in an extreme scenario such as war; otherwise using Chinese services would be too risky. In the Filipino navy case, China might disrupt the satellite communication relied upon by the navy to thwart the military and enhance China's military capability. Note, however, that not all service disruption is detrimental to the host countries. For example, were China to discontinue the training of space-data analysis professionals, that would barely benefit China but instead deplete its diplomatic credence. As such, this study focuses on those risks that may cause harm to a host country's national security.

Defining 11 Variables for 108 Pro jects. This study conducts a risk-benefit assessment of BRI–SIC projects by examining 11 variables that are relevant to the Three Questions of Concern posed earlier that identify the features of the BRI–SIC and China's potential purpose for pursuit of a project. This study does not measure the *level* of likelihood that an adverse impact may occur but rather the *possibility* of such an occurrence. The following summarizes the 11 variables, their rationale, and their scope.

1. China is the principal service provider
   - Who are the project's contractors?
2. The service is related to satellite data use, including training/education
   - This variable indicates the service type of a project to determine whether the BRI–SIC is primarily targeted to enhance China's spacefaring capability or is more related to data/content and business-focused.

- This study categorizes services into the following four types (which are not specified in Appendix 1):
  - "Satellite operation-related" includes satellite manufacture and delivery, launch, satellite operation collaboration, ground station construction, and operation.
  - "Data/information-related" includes BDS applications, satellite data business, satellite data sharing, training, education, and demonstration of data application.
  - "China's CORS constructions" for GNSS signal reception.
  - "Chinese ComSat use" includes projects where governments or companies of the host country use Chinese satellites to provide communication.

3. The service is BDS-related
   - This variable examines the type of satellite the project uses (earth observation, communications, or PNT) and whether BDS is a core part of the BRI (as asserted by the *New York Times* article and as articles in Nikkei emphasize[111]).
   - Where a project does not identify which specific type of satellite is used, particularly if its ground station–related, they are not counted within this variable.

For the host country, the project can:

4. Enable infrastructure and connectivity
   - This variable identifies whether the project can benefit the host country by enabling its critical infrastructure since space assets can be a "super-enabler of critical infrastructure."[112]
   - This study employs the US Cybersecurity & Infrastructure Security Agency's definition of the 16 critical infrastructure sectors: chemical, communications, dams, emergency services, financial services, government facilities, information technology, transportation system, commercial facilities, critical manufacturing, defense industrial base, energy, food and agriculture, health care and public health, nuclear reactors, materials, and waste, and water or wastewater systems.[113]
5. Benefit commercially
   - This variable does not examine "economic" benefits as that would be overly broad.

- This variable includes projects that generate profit mainly for local companies/governments rather than Chinese vendors.
- This variable includes those projects where local companies deal with satellite operations and satellite-related data/communications with or without China.
- This variable includes the use of satellites delivered by China and owned by the host government to generate profit.[114] For the same reason, ground station operations and CORS network constructions are included as the foundations of commercial benefit.

6. Benefit national security

- "National security" is defined as the security of a nation-state as a whole, as opposed to human security focused on the security of individuals. A project benefits the national security of the host when it improves defense of the nation from intentional adversarial action.
- This variable is identified from information on the purpose(s) of a project and is based on the general utility of satellites and their data. BDS application projects that do not specifically mention usage for national security are not included in this category, but general training of BDS use is included.
- Since space assets are essentially military-civil dual use (as discussed earlier), this study assumes that countries who have few satellites would naturally want to maximize the utility of their satellites and may use them for national security and civilian purposes. Accordingly, this variable includes EO and communications satellites operation, ground station operation, and CORS networks.

7. Strengthen human security

- "Human security" is defined herein by reference to the UN: to secure "the survival, livelihood and dignity of people" by responses that "strengthen the protection and the empowerment of all people." In this context, the UN specifically mentions responses to three items: "extreme poverty and marginalization," "conflicts," and "natural disaster."[115]
- This variable includes projects potentially beneficial to respond to the three items listed above. This study regards projects that secure food and primary industries as a response to extreme poverty.

- This variable does not include general economic benefits despite the fact they may indeed strengthen human security indirectly or in the long run.
- Both EO and communications satellites are critical at the time of emergency responses including natural disaster. Therefore, satellite/ground station–related activities are included in this category.
- According to a study on cybersecurity, CORS networks are useful for disaster management as was demonstrated in the 2011 Great Tohoku earthquake in Japan.[116] Therefore, CORS network construction is included into this category.

8. Provide tech transfer opportunity
   - This variable includes only technology transfers that help the host country develop its own space-related industry in the long term. This does not include training of how to use Chinese equipment such as BDS receivers.
9. Allow China to share data without authorization
   - This variable inquires whether a project is vulnerable to unauthorized data sharing with China.
   - For those projects specifically designed to share data with China, there is no such vulnerability.
10. Risk its national security by allowing China to share national security–related data without authorization
    - China is accused of being irresponsible with certain commercial data[117] and actively collecting data[118] because data is "the world's most valuable resource."[119] The more information one possesses about a counterpart, the better the ability to tailor strategy toward it.
    - A report on cybersecurity asserts: nation-states engage in long-term espionage and offensive cyber operations that support geopolitical and strategic policy objectives,[120] and a pointed example is China's strategies that highlight the value of information in waging war（情報戦).[121]
    - According to the above-mentioned study on CORS cybersecurity and an expert who works for GNSS receivers, receivers and CORS stations are vulnerable to data exploitation and possible disruption of services.

11. Risk its national security by allowing China to disrupt services in extremis

    - Disrupting the services that a project delivers can endanger the national security of the host country. For example, Laos military uses LaoSat-1. Disruption of this satellite's communications in an extreme situation such as war would impede its military operations.

Note

- Whether a project becomes a risk or is not a risk depends on whether the host country sees the provider as a threat. For example, the UK and Japan would willingly use US-manufactured satellites or GPS receivers since the US is not perceived by them as a threat to their national security. The UK and Japan share national security data with the US in any event and are comfortable that the US would not deliberately and nefariously disrupt those against its allies. Likewise, Iran, Venezuela, and Pakistan may view China in a similar way. This study examines the risk variables 9 through 11 based on the assumption that China can be adversarial to any of the BRI members; the variables are not assessed in the context of whether a host nation considers China as a friend or possible threat.
- This study uses the word "can" in the variables because it is not possible to determine how a project actually functions and one must focus on the potential use thereof.

Risk-Benefit Analysis. The risk-benefit analysis is summarized in Appendix 1 and is based on the references in Appendix 2 corresponding to the numbered project. The risk analysis employs the references in the section titled "References for Risk Assessment" following the endnotes.

Findings

Analysis of 11 Key Findings

Graphic illustrations of each finding are provided in figure 3 below:

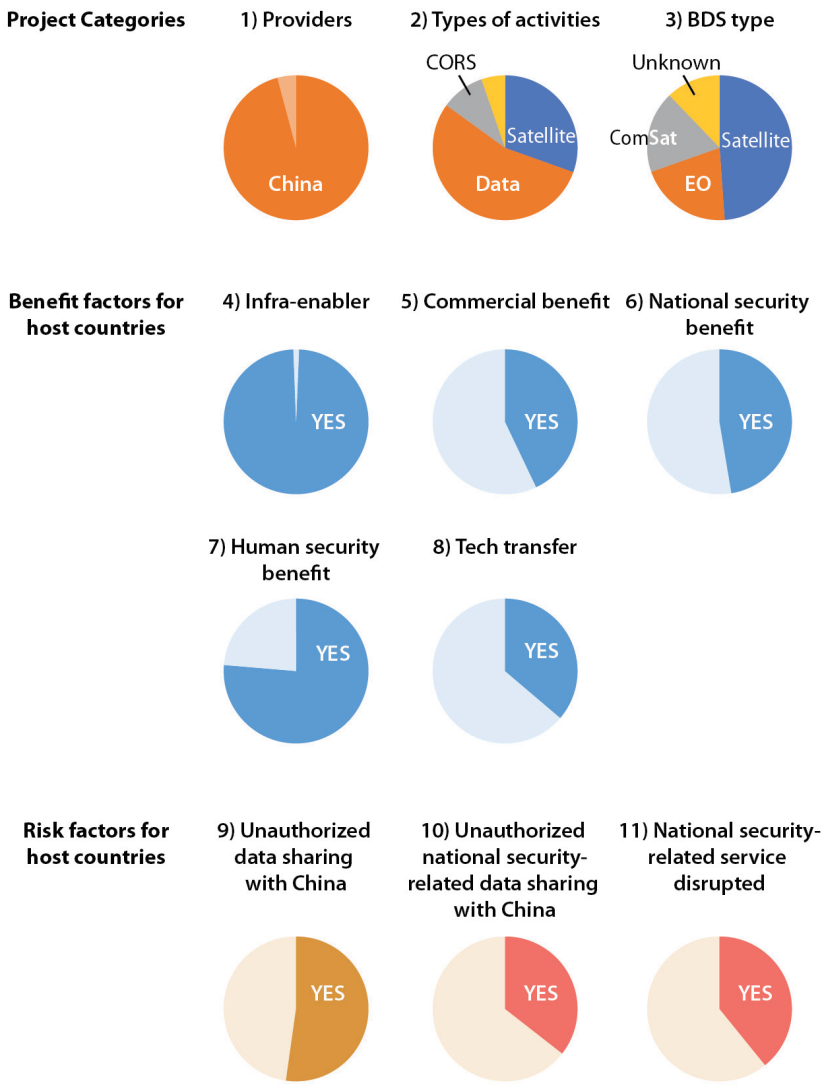


Figure 3. Findings on 108 Belt and Road Initiative Spatial Information Corridor projects

The first three findings reflect all 108 projects. The remaining findings are for 107 projects because the Malindi station in Kenya is eliminated due to there being too little information for inclusion in these other findings.[122]

1. Providers
   - 104 projects (96.3%) had Chinese entities (government agencies or companies) as their sole principal service provider(s).
   - Four projects are either those whose service providers are not clear or those who seem to have equal partners
2. Type of activities
   - Satellite operation–related: 30.5% (33 projects)
   - Data/information–related: 54.6% (59 projects)
   - BDS CORS construction: 10.1% (11 projects)
   - Chinese ComSat use: 4.6% (5 projects)
3. Satellite type
   - BDS-related: 49.0% (53 projects)
   - Remote sensing–related: 20.3% (22 projects)
   - Communications-related: 18.5% (20 projects)
   - Unknown 12.0% (13 projects)
4. Infrastructure enabler
   - All 107 projects are purported to be infrastructure enablers for the host country.
5. Commercial benefit
   - 43% (46 projects) can benefit the host country commercially.
6. National security benefit
   - 47.7% (51 projects) can benefit national security of the host country.
7. Human security benefit
   - 76.6% (82 projects) can strengthen human security of the host country.
8. Technological transfer
   - 36.4% (39 projects) can transfer technology to the host countries.
9. Unauthorized data sharing with China
   - 52.3% (56 projects) have the possibility that China shares data without authorization.
   - 47.6% (51 projects) are projects aimed to share data with China, or China provides data/training or education Of these, 31 projects are

collaborations with China, and 22 projects are for China to unilaterally provide data/information to host countries. Some projects have both aspects.

10. Unauthorized national security–related data sharing with China

    - 35.5% (38 projects) can allow China to share national security–related data of the host country without authorization.

11. National Security risk by service disruption/discontinuation

    - 39.3% (42 projects) can endanger national security of the host country if China disrupts the service.

Implications of This Study. The data examined in this study indicate the following:

From China's perspective

- One reason why the BRI–SIC causes concern is that since space-related assets and technology are of dual-use in nature and the Guiding Opinion specifically dictates that the BRI–SIC be based on MCF, then the BRI–SIC projects may strengthen the PLA.[123] However, this study found no clear sign that China intends to use BRI–SIC *primarily* to enhance its military capability. Satellite delivery–related projects (including ground station construction) involving the PLA-related SOEs represent only 30.8% (although it is possible that percentage increases in the future).
- Another uneasiness about the BRI–SIC for the US and its allies is that China may intend to use the Space Silk Road to dominate outer space since China has been rapidly developing its space capability.[124] This study finds that BRI–SIC is more focused on global expansion of data businesses, particularly those of BDS, rather than outer space capability, although satellite delivery–related projects involve the highest expenditure by China within the BRI–SIC initiative. Of the 108 projects, 21 are satellite-related (China manufactured and launched 15 satellites and plans to do so for a further six satellites). Launches involving BRI–SIC projects are a small fraction of the 393 launches undertaken by China as of October 24, 2021.[125] BRI–SIC does not appear to be designed to increase China's spacefaring capability.
- Satellite delivery projects enhance China's positive image in three ways. First, the projects are highly beneficial to the host nation. In this examination, of the "Five Benefit Factors" (enabling infrastructure; commercial benefit; strengthening national security; strengthening human

security; and technology transfer), satellite delivery projects exhibit all except technology transfer. China and the government of the host countries can advertise these benefits as a significant contribution by China. Second, contrary to data processing or setting up GNSS receivers that are often not visible or made public, provision of satellites is dramatic and can boost the host countries' national pride.[126] China's contribution can be highly appreciated. Third, such projects symbolize China's advanced technology and goodwill. While such projects also ensure more risks than other types of projects, these risks are potential in nature and many have low likelihood of realization, yet the benefits are substantial.

- Demand for space-related services will increase among the BRI host countries due to their economic growth and climate change. China is active in providing operational support to permeate markets. All told, 23 projects involve demonstration, service support, training, education, and research cooperation to promote China's BDS-related projects or the remote sensing data application industry. Such provisions help Chinese vendors successfully establish customer and sales networks and a positive image as a service provider in the BRI countries prior to that demand crystallizing. Chinese vendors are expected to benefit from the increased future demand as the incumbent vendors.
- As Finding 9 indicates, 81.3% (87 projects) can provide data/information to China about host countries with or without their authorization, in some cases by cooperation between ground stations or data processing parks, and in other cases with China possibly eavesdropping through equipment provided by Chinese vendors. In addition, CORS constructions do not only provide an opportunity for China to gain access to data; they also enhance the accuracy of the data from BDS signals. The BRI–SIC projects may not materially strengthen the PLA's military capability, but the collected information gained through it can be useful for the PLA. In this way, the BRI–SIC can extend China's data/information gathering capability and business opportunities for its vendors.

From the host nation's perspective

- The BRI–SIC carries more benefits than risks for the host countries. All 107 projects studied here with sufficient available information exhibit more potential benefits than risks based on the premise that there are only two possible risks in hosting BRI–SIC services. Out of 107 proj-

ects, 46 exhibit benefits with no risk; and 33 out of 107 projects display four or five benefits out of the "Five Benefit Factors" listed above.

- As explained earlier, whether a project is a risk depends on whether a host sees the provider as a potential threat. If this study were to categorize each of Laos, Cambodia, Myanmar, Pakistan, Iran, Nigeria, and Venezuela as not viewing China to be a threat but an ally, the number of projects that display only benefits without risks increases from 43% to 63.6% (68 projects).

Answers to the Three Questions of Concern. Based on the findings examined above, this study answers the Three Questions of Concern. In turn, these answers help address the core question: Should the US and its allies be concerned with China's global expansion of space-related activities in the name of BRI–SIC? Based on the riskbenefit factors examined herein:

Q1: Do most of BRI–SIC projects increase China's spacefaring capability?
NO. Finding 2 (Type of Activities) indicates that 30.8% (33 projects) are related to spacefaring activities (21 satellite in-orbit-delivery deals, nine ground station construction/cooperation, two launch-only, and one satellite manufacturing cooperation). About 70% of the projects do not aid building China's spacefaring capability. While China seeking to increase its spacefaring capability can be a part of the BRI–SIC's objectives, this does not appear to be a primary goal.

Q2: Are most of the projects useful for China to strengthen its national security?
NO. Findings 10 and 11 (Risk-Related) both indicate that approximately one-third of the projects can assist China's national security, either by providing host country's national security–related information to China or by allowing China to disrupt the services it provides to undermine the host country's national security.

Q3: Do most BRI–SIC projects risk national security of the host countries rather than provide benefit to them?
NO. The Risk-Benefit Assessment (Appendix 1) shows that no project exhibits more risks than the potential benefits the service provides to the host country (noting the premise that this study recognizes only two types of national security risk of the BRI–SIC projects). Thus, 43% (46 out of 107 projects) provide only benefits without risks. If, as mentioned earlier, certain countries do not view China as a threat, the number of projects that have only benefits increases to as high as 63.6%. Overall, the BRI–SIC appears to be more beneficial than risky to the host countries.

These answers to the Three Questions of Concern suggest that, to date, the US and its allies need not be overly concerned about the BRI–SIC enhancing China's military-related capability. While that remains subject to changing in the future,

the US and its allies can take action to prevent an unfavorable situation from occurring as discussed in the recommendations outlined in the next section.

Conclusions

It would not be surprising for one to initially view China's BRI–SIC initiative through a skeptical lens. This study conducted a risk-benefit assessment of 108 identified BRI–SIC projects and finds that the US and its allies should indeed be concerned with China's global expansion of space-related activities under the BRI–SIC. More specifically, however, that concern ought not be directed at China enhancing its military capability or even spacefaring capability. On the face of it, the BRI–SIC does not appear designed to optimize China's own capabilities of this nature. Instead, the BRI–SIC provides China with more data/information about each country and positive influence, or soft power,[127] over it and enhances China's business opportunities, resulting in a possible shift in the geopolitical balance of power.

Is China weaponizing the BRI–SIC projects? According to former US State Department senior official Daniel Russel, China is "weaponizing BRI by creating a Sino-centric ecosystem of trade, technology, finance and strategic strongpoints."[128] China is certainly leveraging the BRI–SIC to establish its own ecosystem in the space-related data/information domain. Following her investigation of a Chinese translation company, Samantha Hoffman concludes: "Whoever has the opportunity to access the data a product generates and collects can derive value from the data."[129] Relatedly, is China "undermining American Influence and role as a security guarantor"[130] by providing BRI–SIC projects? It appears so. China is enhancing its influence through such provisions, thereby reducing the relative power of the US. Nonetheless, this study does not conclude that the purpose of BRI–SIC is for China to undermine American influence, despite that being a possible collateral outcome. Rather, it reveals that BRI–SIC is used by China to secure global markets to further its data/information-based economic growth.

Throughout his book *The Digital Silk Road*, Jonathan Hillman emphasizes that China prevails in areas where there are no viable alternatives for host nations, either because that market is not recognized by others or the cost of services provided by others is prohibitive. Consequently, China's input and resources are appreciated by the clients and, as such, "fear alone does not stop [the Digital Silk Road]."[131] This study concurs and illuminates the reality that, despite potential risks attached (which are less than perhaps perceived), the government and individuals in a host countries may appreciate services provided by the BRI–SIC projects, as those might otherwise not be available without pro-

vision by China. The US and its allies need not focus on the risks attached to these Chinese services just yet but rather the absence of alternatives. If the only option is to Chinese services, then naturally that dependence translates to China being positioned to hold an element of leverage over the host countries.

The US and its allies are increasingly critical of China for its elevated internal and external aggressions and tightened controls. But other nations across the globe may not share that same view and perception of China. A Brazilian official said to the author of this study: For Brazil, China is not necessarily more malicious than the US.[132] Biased interpretations of China's activities can lead to inappropriate or uninformed responses thereto. If one objectively reviews the risk-benefit assessment that this study provides, the response of the US and its allies to the BRI–SIC ought not be to warn the host countries of risks of the use of Chinese-provided services. Rather, the US and its allies must provide attractive alternatives to the BRI–SIC. To that end, recently proposed alternatives to the BRI, including the "Build Back Better World" initiative introduced at the G7 by the Joseph Biden administration and the "Global Gateway" by the European Union, align with this study's recommendations. Space-related projects and initiatives must be within the scope of these programs. Otherwise, China will successfully create a significant ecosystem in the space-related domain, which will grow quickly, span to a large populous across the globe, and be supported by enthusiastic BRI host countries.

Appendix 1: Project List and Risk-Benefit Assessment

1. China is the principal service provider
2. The service is related to satellite data use, including training/education
3. The service is BDS-related
For the host country, the project ***can*** __
4. enable infrastructure and connectivity
5. benefit commercially
6. benefit its national security
7. strengthen its human security
8. provide tech transfer opportunity
9. allow China to share data without authorization
10. risk its national security by allowing China to share national security–related data without authorization
11. risk its national security by allowing China to disrupt the service in extremis

	Country	Type	Project	Year mentioned /status	China-related Funding	Relevant agencies/activities/ notes (from references)	1	2	3	4	5	6	7	8	9	10	11
							104	59	53	107	46	51	82	39	56	38	42
1	**BRI** 145 countries (As of 2022. Green Belt and Road Initiative Center)	DTS	FengyunCast/CMACast, a satellite broadcasting service of meteorological data	2007		-CMA -A part of Global Earth Observation System of Systems(GEOSS)) -China shares its meteorological data from Fengyun remote sensing satellites by providing data receivers to Asia-Pacific countries (17 countries by 2007) -" Keep track on typhoons and torrential rain in the region, providing information for TV weather programs, as well as helping monitor the risk of floods, droughts, heavy fog, sea ice, river sediment blockages, forest and prairie fires, and sand-and-dust storms."	✓	✓		✓			✓				

2	DTS	Disaster Prevention and Mitigation Emergency Support Mechanism (FY_ESM)	2018-	-CMA -SASTIND -APSCO -A part of "FY Meteorological Satellite Service 'Belt and Road Action Plan (2019-2023)" -China shares its remote sensing data/information from Fengyun -Fengyun satellites help build space information corridor and prevent and reduce disasters in the Belt and Road members -98 participant countries (June 2020)	✓	✓		✓		✓	
3	TER	International Training Courses for Meteorological Science	2014-	-CMA -"This training course will help the trainees deeply understand the spirit of speeches on technological innovation given by president Xi, in order to carry out the system reform, accelerating the meteorological innovation" -1,440+ people from about 90 countries have trained (March 2021)	✓	✓		✓		✓	✓
4	TER	International Training Course on Space and Satellite Applications	2015	-BeiDou International Exchange and Training Center -UN-affiliated Asia-Pacific Regional Center for Space Science and Technology Education -Beihang University -CGWIC -CNSA -MIIT	✓	✓	✓	✓		✓	✓

5		TER	International Training Workshop on BeiDou Technology and its Applications for BRI countries	2018	-15-day course to understand space information technology, satellite navigation, satellite communication and remote sensing -Academic Exchange Center of CSNO -Aerospace Information Research Institute (under CAS) -CAS Bureau of International Cooperation -All expenses, including accommodation and airfares, are paid by China	✓	✓	✓	✓		✓	✓			
6	**ASEAN** (10 countries: following nine countries plus Vietnam)	COS	APSTAR-6C	2018 launched	-Communication satellite -CGWIC singed (IOD), CAST manufactured -APT Satellite Company (Hong Kong) -Services to customers across the Asia-Pacific region for VSAT, video distribution, DTH and cellular backhaul applications. -"To support the Belt and Road Initiative"	✓			✓		✓	✓		✓	✓	✓
7		DTS TER	China-ASEAN Remote Sensing Satellite Data Sharing and Service Platform Project	2012	-China Centre for Resources Satellite Data and Application (under CASC) -Sharing data from CBERS-04 -National University of Singapore for data reception and processing (150,000 image data collected in 2018) -For ASEAN's social and economic development -'Improves China's international influence.'	✓	✓		✓		✓	✓			

8	TER	China-ASEAN Satellite Navigation International Cooperation Alliance	2020 completed		-61 academic exchanges and co-construction of laboratories for ASEAN -Guangxi government -Guilin University of Electronic Science Technology	✓	✓	✓	✓		✓	✓
9	DTB	China-ASEAN BeiDou Intelligent Industrial Park (Nanning)	2020 completed		-Guangxi government -120 firms (expected)	✓	✓	✓	✓	✓		✓
10	DTB	China-ASEAN Beidou/GNSS Center (Nanning)	2020 completed		-Guangxi government	✓	✓	✓	✓	✓		✓
11	DTB	China-ASEAN BeiDou Science and Technology City (Thailand)	2015 signed	-1.545b. yuan (hubei.gov.cn) --10b. yuan /$1.45b. (Global Times)	-BDS application service platform, industry development platform for ASEAN -Wuhan Optic Valley BeiDou Holding Group	✓	✓	✓	✓	✓		✓
12	DTB	Guangxi-ASEAN Geographic Information and Satellite Application Industrial Park	2016-	-1.43b. yuan	-Data application research, incubation, development, information exchange, talent training -Guangxi government -To have 260 units by 2024	✓	✓		✓	✓		✓
13	DTB	Lancang-Mekong Spatial Information Exchange Center	2018 under construction		-Remote sensing application service platform jointly established by China, Thailand, Laos, Myanmar, Cambodia -A part of BRI-SIC	✓	✓		✓	✓		✓

14		BDA TER	China-Lao-Cambodia BDS positioning demonstration project	2018		-Aerospace Information Research Instutute (under CAS) -China provided two overseas reference station system and 15 portable termnal systems for BDS -Training of professionals from ASEAN countries	✓	✓	✓	✓			✓				
15	Brunei	BDA	BDS civil applications	2013		-Urban construction, including a modern capital building -Smart turism -BDS-related tech transfer -BDS-related job creation	✓	✓	✓	✓			✓	✓			
16		BDC	CORS network setup	2013			✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
17	Indonesia	SAT	Paluapa-N1/Nusantra Satu-1	2020 launch failed	-Com-mercial loan support	-Communication Satellite for BRI members -CGWIC (IOD, including financing), CAST manufactured	✓			✓	✓	✓	✓		✓	✓	✓
18		COS	Using China's ComSat	2017		-China Satcom (under CASC) - 'Marine Tel' brand -Support Indonesia's navy, police and aviation -In support of BRI/Maritime Silk Road	✓			✓		✓	✓		✓	✓	✓
19		DTS	Sharing remote-sensing data	2014		-Remote sensing data sharing for maritime security -CNSA -Indonesian Maritime Security Coordinating Board	✓	✓		✓		✓	✓				✓

20		BDA	Land right confirmation project	2018		-1046 sets of receivers procured. The receiver model had been distributed to 80+ countries (35 BRI countries) -For coastline surveying and mapping, land area measure-ment and natural resources exploration -ComNav Technology -Ministry of Agrarian Affairs and Spatial Planning/Nationa Land Agency of Indonesia	✓	✓	✓	✓			✓		✓				
21		BDA	BDS commercial applications	2018		- BDS-related consumer goods - Reasonable prices and better signals than GPS-based applica-tions	✓	✓	✓	✓					✓			
22	Laos	SAT	LaoSat-1	2015 Launched	-$259m. loan from EXIM Bank	-Comunication Satellite -CGWIC (IOD), CAST manufactured - JV with China and Lao Asia Pacific Satellite Co., Ltd. (Laosat) -Lao government 45% ownership -China 55% (Asia-Pacific Mobile Telecommunciations Satellite (under CASC) 35%, Space Star Technology (under CASC) 15%, Asia-Pacific Satellite Technology of China 5%) -Training included in the Funding -Remote learning supported by Education Ministry of Laos -Military has a TV channel	✓			✓	✓	✓	✓	✓	✓	✓	✓	

23	COS	Satellite digital television to 100 villages	2021 Xi agreed at his 2017 Laos visit	-'Chinese-aided rural infrastructure project' -One of Xi's initiative '4x100' : clean water, hospitals, electricity, digital TV -Lao-China Cooperation Commission	✓			✓			✓						
24	BDA	Application to agriculture	2018	-Precision agriculture, disease and pest monitoring	✓	✓	✓	✓			✓		✓				
25	BDA	Land right confirmation project	2018	-CHCNav -ComNav	✓	✓	✓	✓			✓		✓				
26	BDA	Safe City Project in Phongsaly	2018	-To maintain public safety and position police forces	✓	✓	✓	✓			✓		✓				
27	BDC	CORS network setup	2013	-Navigation surveillance, engineering surveying, urban and rural construction, meteorology and disaster response	✓		✓	✓	✓	✓	✓		✓	✓	✓		
28	DTB	China-ASEAN Information Harbor (CAIH) Lao Cloud Computing Center	2018	-China Eastcom (CAIH) in Vientiane -Lao Asia Pacific satellite Co. Ltd. -Guangxi government Science and Technology Deparment -To support smart city, big data, IoT etc. -First client to be a Chinese bank in Laos	✓	✓		✓	✓			✓					

29	Cambodia	SAT	Techo-1	2018 signed, not launched yet	-Cost $150m. estimate	-Communication Satellite -CGWIC (IOD) -For digital broadcasting, satellite broadband, national security, disaster management, and e-goverment -Royal Group of Cambodia as operater -CGWIC: “To promote BRI-SIC”	✓			✓	✓	✓	✓		✓	✓	✓
30		DTS /BDA	Ship Monitoring System (VMS)	2020		-CGWIC -Ministry of Public Works and Transport of Cambodia -National Census of Vehicle Service Providers (NCVSP)	✓	✓	✓	✓		✓	✓		✓	✓	✓
31		BDA	GNSS receivers for land management and UAV for land and environment monitoring	2016		-SinoGNSS -CHCNav for drones -Inter-ministrial working group of Cambodian government	✓	✓	✓	✓			✓		✓		
32		BDC	CORS network setup	2014		-Chinese Government -China Electronics Technology Group Corporation (CETC) -Ministry of Industry and Handcrafts of Cambodia	✓		✓	✓	✓	✓	✓		✓	✓	✓
33	The Philippines	COS	G Telecoms Inc. acquisition	2018		-China Communication Technology (CCT) -For direct TV -To promote “BRI” -Clients include Philippine Navy and maritime security guard	✓			✓		✓	✓		✓	✓	✓

34	Thailand	SAT	High Throughput Satellite	2016 Con-tract, not launched yet	-$208m.	-Communication Satellite -CGWIC signed (IOD), CAST to manufacture -Thaicom	✓			✓	✓	✓	✓		✓	✓	✓
35		GSC	Princess Chulabhorn Remote Sensing Satellite Ground Station	2011		-To monitor flood -China Centre for Resources, Satel-lite Data and Application (under CASC) -Thai Agriculture Univerity	✓			✓		✓	✓		✓	✓	✓
36		BDA	Postal service and E- com-merce platform	2018		-Warehouse management -Beijing BDStar	✓	✓	✓	✓					✓		
37		BDA DTB	Thailand Geospatial Disaster Monitoring, Evaluation and Prediction System Coopera-tion Agreement, including the construction of geospatial information industrial park	2013	-2b. yuan	-Wuhan Information Technol-ogy Outsourcing Service and Research Center -Wuhan University -Thailand Geographic Information and Space Technology Develop-ment Bureau -"Thai government will list the construction of a disaster forecasting system based on Beidou into its overall economic development plan"	✓	✓	✓	✓	✓		✓	✓			
38		BDC	CORS network setup	2013	-$319m.	-Wuhan Optics Valley BeiDou Hold-ing Group -"Promoting BDS is 'great strategic significance to China'"	✓		✓	✓	✓	✓	✓		✓	✓	✓
39		BDA	Khon Kaen Smart City project	2019 MoU		-Guanxi government -A part of BDS promotion and related cooperation	✓	✓	✓	✓					✓		

40	Myanmar	TER	China-Myanmar Rader and Satellite Communication Joint Laboratory		2018	-Cooperation in science and tech transfer -PRC Ministry of Science and Technology -A part of BRI	✓	✓		✓			✓					
41		BDA	GNSS application for fishery and transportation		2020	-1000+ sets of BDS ship-borne terminal products for fishing navigation -Land planning and river transport monitoring	✓	✓	✓	✓			✓		✓			
42		BDA	GNSS receivers procurement for agriculture		2013	-CHC NAV provided 520 sets of receivers -Ministry of Agreculture and Irrigation of Myanmar -Spread to other ministries for procurements	✓	✓	✓	✓			✓		✓			
43		BDC	CORS network setup		2013		✓		✓	✓	✓	✓	✓		✓	✓	✓	
44	Malaysia	DTB		Beidou-ASEAN Data and Service Center	2014	- Disaster warning, vehicle navigation, precision agriculture, maritime search and rescue, smart ports, mineral safety, intelligent transportation -Wuhan Optics Valley BeiDou Holding Group -Malaysian Investment Development Authority -“a part of BRI strategy”	✓	✓	✓	✓	✓		✓	✓				
45		BDC		CORS network setup	2014 planned	-Wuhan Optics Valey BeiDou Holding Group	✓		✓	✓	✓	✓	✓		✓	✓	✓	

46		DTB	Kejia Macro Satellite Application Industry Project	2015	-80+m. yuan	-Beijing Keija Hong Technology Co., Ltd.	✓	✓		✓	✓			
47		DTB	China-Malaysia Satellite Application Industrial Park	2016 signed	-1.9b. yuan total -320m. yuan investment	-Satellite big data application center -Two goverments' cooperation -China-Malaysia Qinzhou Industrial Park Management Committee -Singapore Hongde Group -400,000 m^2 by 2019	✓	✓	✓	✓	✓		✓	
48		TER	Sino-Malaysia Joint laboratory on the application of BDS	2018		-Guangxi government's support -Guilin University of Electronic Technology -Pahang University of Malaysia -To improve accuracy. GPS is not sufficiently accurate	✓	✓	✓	✓			✓	
49	Singapore	TER	Excellence Innovation Center for BDS applications	2014		-China Satellite Navigation and Positioning Association -Sigapore Economic Development Board	✓	✓	✓	✓			✓	
50		BDA	Piling	2018		-CHCNav	✓	✓	✓	✓				✓

51	**APSCO** (7 state + China) - Peru - Bangladesh - Turkey - Mongolia - Pakistan - Iran - Thailand	GSC	Asia-Pacific Ground-Based Optical Satellite Observation System (APOSOS)	2011	-LEO observation via ground optical trackers for space security -To develop a linked space observation network based on optical tackers in APSCO member countries -APOSOS data center built in Beijing hosted by National Astronomical Observations of China (NAOC) -Each member state has a data processing center	✓		✓			
52		DTS TER	Data Sharing Service Platform (DSSP)	2012	-Remote sensing data sharing -Training of remote sensing data processing and applications -To provide full service of the space applications and space technology	✓	✓	✓		✓	✓
53		TER	Small Multi-Mission Satellites (SMMS) Constellation Program	2019	-Members to receive satellite data at their own ground stations -Survey focuses: agriculture, forestry, mineral resource surveying, maritime environment monitoring, navigation safety	✓		✓		✓	✓
54		DTS TER	Seismic-ionospheric Observation Application Platform in Asia-Pacific region (SOAP)	2017	-Sharing data from CSES and other EO satellites and research cooperation -National Institute of Natural Hazards of China (NINH) -Ministry of Emergency Mangament of the PRC (MEMC)	✓	✓	✓		✓	✓

55		DTS TER		Ground-based Ionospheric Monitoring and Information Sharing Platform (GIMI)	2015	-To provide a web portal that provides data, data processing and analysis tools, and real-time user interaction capability -China Earthquake Administration (CEA)	✓	✓		✓		✓	✓
56		DTS TER		Framework for Researches on Application of Space Technology for Disaster Monitoring in the APSCO Member States Projects	2016	-Platform for research on application of space technology to disaster monitoring (flood, earthquake, landslides/avalanches, drought) -Disaster assessment, prediction, early warning and mitigation	✓	✓		✓		✓	✓
57		DTS TER		Development and Demonstration of Application of Compatible GNSS Terminals for Emergency Management and Disaster Rescue (EMDR) Project	2013	-To collect disaster informaiton through emergency terminal, formulate rescue programs based on the informaiton and provide services such as positioinig information, navigation data and communication messages for rescue missions -Participants: China, Bangladesh, Iran, Pakistan, and Thailand	✓	✓	✓	✓		✓	✓
58		TER		APSCO Education and Training China Center	2018	-provide MAs and PhDs -Beihang Univesrity -Creation of APSCO University Alliance	✓	✓		✓		✓	✓
59	Pakistan	SAT	PakTES -A		2018 launched	-Satellite launch only -Satellite developed domestically	✓			✓	✓	✓	

60		SAT	PRSS-1	2018 launched		-Remote sensing satellite -CAST (IOD) personnel training included -To support BRI and CPEC by providing remote-sensing information -For land and resource surverying, monitoring natural disasters, agriculture research, urban construction etc.	✓			✓		✓	✓	✓	✓	✓	✓
61		SAT	PakSat-1R	2011 launched	-$222.3m. China IMEX	-Communication satellite -CGWIC signed (IOD) -Commercial use, mainly for domestic communication, broadcast -Can be used to track, data relay, mobile communication -Pakistani Army uses it	✓			✓	✓	✓	✓		✓	✓	✓
62		GSC	Ground station construction and co-operation with China	2009 signed	-86.5m. yuan EXIM Bank	-TT&C station for PakSat-1R -CGWIC and CASC involved -China provides software and hardware -In Karachi, and backup in Lahore	✓			✓		✓	✓	✓			✓
63		BDC DTB	Five BeiDou network ground stations and one processing center	2014		-UniStrong -“According to the agreement, China provided the Beidou-equipped infrastructure for government and military use at subsidized costs“	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓

64		BDA	Timing application for Pakistan airport information system	2017		-UniStrong	✓	✓	✓	✓		✓			✓	✓	✓		
65		TER	Beihang BeiDou Silk Road Institute	2017 signed		-Beihang University -Pakistan National University of Science and Technology -UN Center for Space Science and Technology Education in Asia and the Pacific (Beijing) -Extending collaboration with other BRI members	✓	✓	✓	✓			✓						
66		BDC	CORS network setup	2013	-'Tens of millions of yuan'	-Beijing BDStar to set up CORS -"To end the dependency on GPS" -"GSP's questionable availability during a conflict"	✓		✓	✓	✓	✓	✓		✓	✓	✓		
67	Iran	TER	GNSS technology transfer project	2015 MoU		-CSNO -Iran Electronic Industries (IEI) in charge of domestic satellite manufacturing -"The US had prohibited Iran's access to high-precision services"	✓	✓	✓	✓	✓	✓	✓	✓					
68		BDC	BeiDou ground stations construction	2015 MoU		-China to construct it -IEI to found a center for space data collection	✓		✓	✓	✓	✓	✓		✓	✓	✓		
	Other South Asia																		

69	Sri Lanka	SAT	SupremeSat-1	2012		-Communication satellite payload -Part of APSTAR-7 payload leased to Sri Lanka and branded as SupremeSat-1 -Satellite operated by China Satcom (under CASC)	✓			✓	✓	✓	✓	✓	✓	✓
70		SAT	SupremeSat-2	2012 approved 2018 post-poned	-Tatwah Smartech acquired 49% of Supreme Satel-lite with $31.3m. (planned)	-Communication satellite -CGWIC signed (IOD) -$320m. total, launching $100m., supplyer credit arranged by an overseas commercial bank -Due to the poor marketing situ-ation, the contract was post-poned in 2018	✓			✓	✓	✓	✓	✓	✓	✓
71		BDC	CORS network setup	2017		-Wuhan Optic Valley BeiDou Hold-ing Group -Agreement concluded when Chi-nese Defense Minister visited Sri Lanka to talk about military cooperation	✓		✓	✓	✓	✓	✓	✓	✓	✓
72	Nepal	TER	Offline/online training of BDS use in Beijing	2020		-CAS -BDS “enhances PLA’s capabilities in conducting overseas opera-tions”	✓	✓	✓	✓		✓	✓			
73	Maldives	BDA	Offshore Piling	2018		-ComNav	✓	✓	✓	✓				✓		

74	**Central Asia**	BDA TER	China-Central Asia BeiDou Cooperation Forum	2019		-Agreements with Central Asian countries to promote application of BDS -Nanning, Guangxi	✓	✓	✓	✓			✓						
75	**Arab Union**	BDA TER	China Arab BeiDou Cooperation Forum	2018		-Demonstrations of BDS-related products/services -CSNO -Arab Informaiton and Communication Technology Organization -Beihang University -China Agricultural University -China Academy of Agricultural Mechanization Science -NORINCO -CGWIC -SinoGNSS, UniStrong	✓	✓	✓	✓			✓					
76		BDA	China-Arab states BDS/GNSS Center (Tunisia)	2018		-UniStrong -Beijing BDStar	✓	✓	✓	✓			✓						
77	Ethiopia	SAT	ETRSS-1	2019 launched	-China covered $6m. out of $8m. for launching	-Remote sensing satellite -CAST -Ethiopian Space Science &Technology Institute (ESSTI) -To support agriculture, environment, mining -ESSTI collaborated with China from designing to manufacturing - ”Expected to save Ethiopia around 350 million birr (about 11 million U.S. dollars) annually it currently spends to receive information from satellites owned by other countries.”	✓			✓	✓	✓	✓	✓	✓	✓	✓

78		SAT	ET-SMART-RSS (EthSat6U, Zhixing 1A)	2020	-$1.5m. -BRI fund -Sunny Group	-Remote sensing satellite -Beijing Smart Satellite Technology -ESSTI and Smart Satellite to collaborate to expand business opportunity in Africa	✓		✓	✓	✓	✓	✓	✓	✓	✓
79		GSC	Continental satellite data receiver station	2020		- In collaboration with China - To disseminate data to African continent (African Union HQ in Ethiopia)	✓		✓	✓	✓	✓				
80	Egypt	SAT	EgyptSat-2 /Misr-Sat 2	2022 to be launched	-$72m. (2019) -$45m. (2018) -$23m. (2016) for space program	-Remote sensing satellite -CASC -Egyptian Space Agency operates -Egypt designed and assembled with China's support -In the name of BRI	✓		✓	✓	✓	✓	✓	✓	✓	✓
81		SAT	Assembly, Integration and Testing Centre construction	2022		-China to build the Centre -Egypt hosts Africa Space Agency	✓		✓	✓	✓		✓			
82		GSC	Ground control station construction and application system collaboration with China	2019		-China to supply the station and application system to support satellite operation	✓		✓	✓	✓	✓	✓			✓

83	Algeria	SAT	AlComSat-1	2017 launched	-	-Communication satellite -CGWIC (IOD) -China Satcom (under CASC) support operation -To support TV broadcast, remote education, e-government.	✓			✓	✓	✓	✓	✓	✓	✓
84		BDA	BDS applications	2019		-For surveying, mapping, precision agriculture, telecommunication, maritime monitoring and/or disaster relief.	✓	✓	✓	✓		✓	✓	✓		
85		BDC	Algeria National CORS network project	2019		-Beijing BDStar	✓		✓	✓	✓	✓	✓	✓	✓	✓
86	Kuwait	BDA	Skyscraper Construction Monitoring	2015		-ComNav provided SinoGNSS receivers -Ahmadiah Company, contractor	✓	✓	✓	✓				✓		
87	Saudi Arabia	SAT	SaudiSat-5A&5B	2018		-Satellite launch only	✓			✓		✓	✓			
88	Sudan	SAT	SRSS-1	2019	-EXIM Bank loan	-Remote sensing satellite -Shenzhen Aerospace DFH HIT Satellite Co. -Civil, national security, and public security (intelligence) application -Exploration of natural resources for military needs, environmental monitoring, agricultural monitoring	✓			✓	✓	✓	✓	✓	✓	✓

89		TER	Regional Smart Agriculture Forum (Beidou Navigation Forum Mechanism)	2018	-2-day training course for application of BDS in the field of precision agriculture to serve 160+ students at the first Forum -CNSO -Arab Information and Communication Technology Organization -Arab Agricultural Development Organization -Beihang University -China Agricultural University -China Academy of Agricultural Mechanization Science -NORINCO -CGWIC -ComNav Technology	✓	✓	✓	✓		✓	
90	Tunisia	BDA	Development of a precision agriculture cooperation demonstration project	2019	-UniStrong -Mejazbab Higher Agricultural Engineering School.	✓	✓	✓	✓		✓	
91	Iraq	BDA	BDS civil applications Construction of BDS/GNSS centers	2019 MoU	-Public security, agriculture engery, transportation, port management, academic exchanges, joinly building BDS centers. -CNSO -Ministry of Communications, Iraq	✓	✓	✓	✓		✓	✓

92	**Africa (excluding Arab countries)**	COS	Africa Satellite TV village project	10,000	2015	-Participant countries often get loans from Chinese EXIM Bank	-TV equipment, including solar energy system -StarTimes (in Africa since 2008) -Training personnel for costumer service -Xi Jingpin's idea pledged at the China-Africa Cooperation Forum -30 African countries (2019) -16,000 households + 2,400 public institutions in Kenya (2018) -Chinese TV shows broadcast to 10 million subscribers	✓			✓		✓					
93	Nigeria	SAT	NigComSat-1R (disordered, replaced)		2007 -1 launched 2011 -1R launched		-Communication satellite -CGWIC signed (IOD) -NigComSat-1 out of order (2008) -1R was delivered for free	✓			✓	✓	✓	✓		✓	✓	✓
94		SAT	NigComSat-2, 3		2018 not yet materialized	-$550m. EXIM Bank	-Two commuication satellites -CGWIC agreed to pay $550m. -"Nigeria has nothing to lose because we are not putting anything into it in terms of financial resources" -"Chinese company will take an equity stake in Nigcomsat, a limited liability company owned the Nigerian government and responsible for managing satellite communications"	✓			✓	✓	✓	✓		✓	✓	✓
95	Uganda	BDA	Land surveying and mapping		2015		-ComNav -Uganda government land surveying and mapping department	✓	✓	✓	✓			✓		✓		

96	DRC	SAT	CongoSat-1	2012 contract on hold	-$320m. valule estimate (financer unknown)	-Communication satellite -CGWIC signed, CAST to manifac-ture -Renatelsat to operate the satellite -Financial issues have kept the proj-ect from being implemented	✓		✓	✓	✓	✓		✓	✓	✓
97	Kenya	GSC	Malindi Ground Station co-operation			-CNSA -Current status unknown, so no assessment is possible -Operated by European Space Agency -A 2011 article mentioned this as one of China's five overseas ground stations -China Aerospace Studies Institute report (2021) also mentions this as 'China's global space infrastructure'									
98	Namibia	GSC	Ground Station construction and co-operation, and opera-tion training			-CLTC -China helped build TT&C station -China has been assisting the sta-tion operation -China trains Namibian students to manage facilities and use space data	✓		✓		✓	✓	✓			

99	South Africa	GSC	Ground Station construction and co-operation	2015		-Ground station construction by China -Center For Resources Satellite Data and Application (under CASC) -To receive and distribute data from BRICS remote sensing satellite network to 13 countries -Internaitonal cooperation, particularly BRICS		✓		✓	✓			
	Latin America													
100	Bolivia	SAT	Tupac Katari-1	2013 launched	-China Development Bank financed 85% of total cost of $302m. (another source, $251.1m. Chinese loan)	-Communication satellite -CGWIC singed (IOD), CAST manufactured -Provide remote learning and telemedicine, too -"Attractive one-stop-shop offerings" -Bolivia, "a country with one of the world's biggest and more accessible reserves of lithium"	✓	✓	✓	✓	✓	✓	✓	✓

101	Venezuela	SAT	VRSS-1	2012 launched		-Remote sensing satellite -CGWIC signed (IOD), CAST manufactured -CAST to build remote sensing data and images receiving stations -CGWIC to provide ground application systems -For "earth resource investigation, environmental protection, disaster monitoring and management, crops yield estimation and city planning etc."	✓	✓	✓	✓	✓		✓	✓	✓
102		SAT	VRSS -2	2017 launched		-Remote sensing satellite -CGWIC signed (IOD), CAST manufactured -CGWIC to provide ground application systems	✓	✓	✓	✓	✓		✓	✓	✓
103		SAT	VeneSat-1	2008 launched	-$241m. GS$165m. Who financed them unknown	-Communication satellite -CGWIC signed (IOD), CAST manufactured -"Telephone communications, fax, videoconferencing, high speed Internet, radio, tele-medicine and tele-education" -Government and military use it, too -Agreement include tech transfer	✓	✓	✓	✓	✓	✓	✓	✓	✓

104	Chile	GSC	Ground Station Co-operation	2011 mentioned	-CLTC built the station and agreed to have an access to 10-m C-band antenna -Currently operated by Chilean space agency -Close collaboration with Xi'an Satellite Control Center and to provide data to Xi'an and Beijing centers -Played a role in supporting Shenzhou flight and Chang'e-1 mission.	✓			✓	✓	✓	✓	✓			✓
	Europe														
105	Russia	BDA	Power line inspection project	2017	-UniStrong	✓		✓	✓						✓	
106		BDA	GLONASS-BDS cooperation	2017	-CSNO -"The two countries plan to place in their own countries measuring stations for the other country's GNSS, on a reciprocal basis"			✓	✓							
107	Italy	DTS	China Seismic-Electromagnetic Satellite (CSES)	2018	-Seismo-electromagnetic satellite -CNSA -China Earthquake Administration -Italian Space Agency -CAST (DFH Satellite Co., Ltd.) contractor -Sharing a satellite for earthquake research. -To "record electromagnetic data associated with earthquakes above 6 magnitude in China and those above 7 magnitude around the world"			✓		✓		✓				

108	Belarus	SAT	BelinterSat-1	2016	-$280.9m. EXIM Bank (15-year loan)	-Communication satellite -CGWIC signed (IOD), CAST contractor -China Satcom bought 8 transponders -Commercial ambition -Nigcomsat (Nigeria) as a partner	✓		✓	✓	✓	✓		✓	✓	✓

Notes:

a. In the table, earth observation satellite (EO) and remote sensing satellite are used interchangeably.
b. Some projects may have benefits other than those assessed here. This study focuses on short/medium-term and/or direct benefits.
c. The projects in the same category may have different benefit assessments depending on the information this study obtained.
d. The languages are quoted from the sources. Therefore, the same meaning can be expressed by different words.
e. This study use BDS as the abbreviation for BeiDou System. But depending on the references, the name can be Beidou or BeiDou.
f. Unless specified, the listed projects are planned, not necessarily in progress.

Appendix 2: References for Each Project and General References

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Appendix 3: Abbreviations

AIRCAS	Aerospace Information Research Institute of the Chinese Academy of Sciences
APOSOS	Asia-Pacific ground-based Optical Satellite Observation System
APRSAF	Asia-Pacific Regional Space Agency Forum
APSCO	Asia-Pacific Space Cooperation Organization
ASEAN	Association of Southeast Asian Nations
BDS	BeiDou System
BRI	Belt and Road Initiative
BRICS	Brazil, Russia, India, China and South Africa
BRI-SIC	Belt and Road Initiative–Spatial Information Corridor
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance
CAS	China Academy of Sciences
CASC	China Aerospace Science and Technology Corporation
CASI	China Aerospace Studies Institute (Air University of U.S.)
CASIC	China Aerospace Science & Industry Corporation
CAST	China Academy of Space Technology
CBERS	China-Brazil Earth Resource Satellite
CCP	Chinese Communist Party
CCSDS	Consultative Committee for Space Data Systems (U.S.)
CCT	China Communication Technology Co. Ltd.
CCTV	China Central Television
CEA	China Earthquake Administration
CETC	China Electronics Technology Group Corporation
CGWIC	China Great Wall Industry Corporation
CGTN	China Global Television Network
CLTC	China Launch and Tracking Control
CMA	China Meteorological Administration
CMC	Central Military Commission
CNSA	China National Space Administration
COPUOS	Committee on the Peaceful Uses of Outer Space (under the U.N.)
CORS	Continuously Operating Reference Station
CPEC	China Pakistan Economic Corridor

CRESDA	China Centre for Resources Satellite Data and Application
CSES	China Seismic-Electromagnetic Satellite
CSIS	Center for Strategic and International Studies
CSNO	China Satellite Navigation Office
DSSP	Data Sharing Service Platform
EDD	Equipment Development Department
EMDR	Emergency Management and Disaster Rescue Project
EO	Earth observation
ESA	European Space Agency
EXIM Bank	China Export Import Bank
FY_ESM	Fengyun Emergency Support Mechanism
GAD	General Armament Department
GEO	Geosynchronous Earth Orbit
GEOSS	Global Earth Observation System of Systems
GIMI	Ground-Based Ionospheric Monitoring and Information Sharing Platform
GISTDA	Geo-Informatics and Space Technology Development Agency (Thailand)
GLONASS	Global Navigation Satellite System (Russia)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IOD	in-orbit delivery
IoT	Internet of Things
ISR	Intelligence, Surveillance, and Reconnaissance
ISS	International Space Station
ITAR	International Traffic of Arms Regulations
ITU	International Telecommunication Union
LBS	location-based services
JAXA	Japan Aerospace Exploration Agency
JV	joint venture
LEO	low earth orbit
MCF	military-civilian fusion
MEMC	Ministry of Emergency Management of the PRC

MIIT	Ministry of Industry and Information Technology of the PRC
MOST	Ministry of Science and Technology of the PRC
NAOC	National Astronomical Observatories of China
NASA	National Aeronautics and Space Administration (U.S.)
NCVSP	National Census of Vehicle Service Providers (Indonesia)
NDRC	National Development and Reform Commission
NINH	National Institute of Natural Hazards of China
NIST	National Institute of Standards and Technology (U.S.)
NOAA	National Oceanic and Atmospheric Administration (U.S.)
NORINCO	China North Industries Group Corporation
PLA	People's Liberation Army
PNT	Positioning, Navigation, and Timing
PRC	People's Republic of China
SASTIND	State Administration for Science, Technology and Industry for National Defense
SDA	Space Development Agency (Department of Defense, U.S.)
SMMS	Small Multi-Mission Satellites Constellation Program
SOAP	Seismic-Ionospheric Observation Application Platform
SOE	state-owned enterprise
SSA	space situational awareness
TT&C	Telemetry, Tracking, and Command
UAV	unmanned aerial vehicle
UN	United Nations
UNOOSA	U.N. Office for Outer Space Affairs
USCC	US-China Economic and Security Review Commission
VMS	vessel (ship) monitoring system

Appendix 4: Chinese Vendors/Brands Relevant in this Research

BDStar Navigation	北京北斗星通导航技术股份有限公司 https://www.bdstar.com	BeijingBDStar Navigation Technology Co., Ltd.
CASC	中国航天科技集团有限公司 http://www.spacechina.com/n25/index.html	China Aerospace Science and Technology Corporation
CASIC	中国航天科工集团有限公司 http://www.casic.cn	China Aerospace Science & Industry Corporation Ltd.
CETC	中国电子科技集团公司 http://www.cetc.com.cn	China Electronics Technology Group Corporation
CGWIC	中国长城工业集团有限公司 http://www.cgwic.com	China Great Wall Industry Corporation
CHCNAV	上海华测导航技术股份有限公司 http://www.huace.cn/about/intro; https://www.chcnav.com/index	Shanghai Huace Navigation Technology Ltd.
NORINCO	中国北方工业集团有限公司 http://www.norincogroup.com.cn	China Northern Industries Group Corporation Ltd.
SinoGNSS	上海司南卫星导航技术股份有限公司 http://www.sinognss.com	ComNav Technology Ltd.
UniCoreComm	和芯星通科技（北京）有限公司 https://www.unicorecomm.com	Unicore Communications, Inc. (Subsidiary of BDStar) Navigation
UniStrong	北京合众思壮科技股份有限公司 http://www.unistrong.com	Beijing UniStrong Science & Technologies Co., Ltd. (Brand including Hemisphere)
Wuhan Optic Valley	武汉光谷北斗控股集团有限公司 http://www.bdqljcggfw.com/index.php/List/24.html	Wuhan Optics Valley Beidou Holding Group Co., Ltd.

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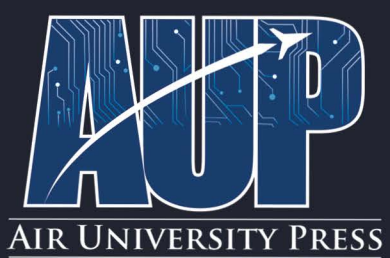

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