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China, Africa, and the Rest: Recent Trends in Space Science, Technology, and Satellite Development

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ABSTRACT

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CHINA'S INVESTMENTS IN AFRICAN COUNTRIES HAVE received significant attention since the turn of the millennium, but outer space cooperation has scarcely been mentioned in policy and research literature. While most space activity in Africa is driven by Africans, outer space cooperation between China and African partner states epitomizes the intersection of peaceful development and security interests of all parties involved. Space infrastructure is crucial to the more commonly studied dimensions of Africa-China relations. This working paper reviews the range of bilateral and multilateral space endeavors through which African countries partner with China and several other international entities and provides recommendations for further research.

INTRODUCTION

THE IMPORTANCE OF OUTER SPACE TO CHINA-AFRICA RESEARCH & ANALYSIS

CHINA'S INVESTMENTS IN AFRICAN COUNTRIES HAVE RECEIVED significant attention since the turn of the millennium, but outer space cooperation has scarcely been mentioned in policy and research literature. Outer space cooperation between China and African partner states epitomizes the intersection of peaceful development and security interests of all parties involved. Increasingly, China and African countries are constructing remote sensing satellite networks in order to support logistical integration of Belt and Road (BRI) partner states and to manage natural disasters, with some security and surveillance applications.[1]

This working paper reviews the range of space endeavors through which African countries partner with China and several other international entities. Within the space sector, satellite development has seen the broadest bilateral activity and greatest national investment. This is, in part, because the development of satellite technologies involves a vast array of complementary industries, from optics to metallurgy to data management, so public investments in satellite development stimulate a range of sectors. More fundamentally, national development as it is conventionally understood requires space-based technologies. Domestic capacity in this field is now considered essential, not only by the governments of African states, but by the United Nations, World Bank, and other multilateral organizations that endorse the 2030 Sustainable Development Goals.

Satellites are crucial to activities that have formed the core of China-Africa research agendas, such as mineral surveying, infrastructure siting and construction, agricultural production, deforestation monitoring and climate cooperation, as well as interoceanic trade.[2] While satellite infrastructure is central to these dimensions of China-Africa cooperation, space cooperation has also demonstrated synergistic effects on economic and diplomatic relations, both of which have been the subject of more sustained media, policy, and scholarly attention. For China's Ministry of Foreign Affairs, space cooperation is generally reserved for those governments with which it has signed "Strategic Partnerships" or "Comprehensive Strategic Cooperative Partnerships" (CSCP).[3] CSCPs are designations reserved for the highest level of bilateral relations, which involve the full pursuit of cooperation, development, and coordination on regional and international affairs.[4] As such, the paucity of research in the outer space domain represents a considerable oversight in China-Africa research and analysis.

This oversight is widespread. There is a general lack of awareness outside of the space sector, and in the North American context more specifically, of space activities on the African continent over the past half century. In African countries, staff of domestic space agencies lament the misperceptions among the general public regarding the role and status of national space development programs.[5] Some agencies, such as Nigeria's National Space Research and Development Agency (NASRDA), have employed media and corporate communications specialists in order to promote greater public awareness at home and abroad. In African countries and

elsewhere, promoting space development in national development narratives is important for justifying annual outlays of public funds in the face of competing domestic priorities.[6] The oversight may also be a result of disciplinary specialization: What may be self-evident and routine to space scientists engaged in South-South and transnational collaborations with African counterparts is outside the more conventional realms of inquiry for most policy researchers.[7] Although this is changing, the result has been that many significant space-related developments in African countries have gone undocumented.

This is not merely an academic concern. The robust social science research on China-Africa relations published in the Euro-American world since the turn of the millennium has informed the foreign policies of many Western governments. In some cases, this scholarship has served as an important corrective to unsubstantiated alarmism that periodically circulates in media coverage. By contrast, if one conducts an English-language Internet search on the subject of China-Africa space cooperation—which is the typical starting point for civil servants and journalists looking into the matter—several pages of sensationalized headlines appear, framing the issue primarily as one of China using space cooperation with African counterparts in order to compete with the West.

For US audiences, the most basic clarification is this: China is not displacing the US in satellite cooperation with African countries due to the simple fact that there have been very few US programs to displace. Space cooperation with African governments has not been a priority area for contemporary US foreign policy, so it is not accurate to represent Africa's space sector as a domain in which China is "taking over."[8] The exaggeration of China's role relative to other partners can also have the effect of erasing the agency of African governments, firms, and science and policy leaders in building extensive space capacity on the continent, not to mention their central roles in shaping international space law since the 1950s.[9] More broadly, outer space is enshrined as the "province of all [hu]mankind" and is therefore open to the "peaceful use" for all in one of the most robust treaty regimes in modern history, the 1967 *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*.[10] This treaty, to which all major space-faring states are party, was formulated with the vision that access to space would eventually be enjoyed by all, not just the front-runners of the US and the former USSR. For the most part, this doctrine of peaceful use has prevailed, enabling the safe placement of keystone technologies for scientific research, communications, and economic globalization in Earth's orbits.[11]

Although China's space agency is often discussed as a wholly state-owned and state-run organization, it behaves like other major space agencies by working with private contractors in procurement and engaging in competitive bidding processes.

As Table 1 shows, fourteen of continental Africa's fifty-four countries have active space programs and dozens of others have the capacity to process satellite data.[12] Together, they have launched forty-two satellites as of January 2020. Ninety percent of the space projects in Africa have been funded by African governments and investors.[13] Russia has launched the greatest number of satellites for African agencies with thirteen completed launch contracts, followed by France (10), the US (8), China (5), India (4), and Japan (2).[14] In addition to China's National Space Agency (CNSA), several

other agencies have had active partnerships on the continent for many years, including Brazil's National Space Research Institute (*Instituto Nacional de Pesquisas Espaciais – INPE*), Russia's *Roscosmos*, Japan's Aerospace Exploration Agency, and a number of European agencies. Space programs in Africa vary in their history and composition, but they are all internationally embedded: When African space programs request bids for satellite contracts, Chinese firms compete alongside other international firms to offer the most competitive package.

Table 1: Continental African Space Agencies

Country	Space or Space-related Agency	Founded	Satellites Launched
Algeria	Algerian Space Agency (ASAL)	2003	6
Angola	National Space Programme Management Office	2013	1
Egypt	Egypt Space Agency	2018	9
Ethiopia	Ethiopian Space Science and Technology Institute (ESSTI)	2016	1
Gabon	L'agence Gabonaise d'Etudes et d'Observations Spatiales (AGEOS)	2007	0
Ghana	Ghana Space Science and Technology Centre (GSSTC)	2011	1
Kenya	Kenya Space Agency	2017	1
Libya	Libya Center for Remote Sensing and Space Science (LCRSSS)	1989	0
Morocco	The Royal Center for Remote Sensing Space (CRTS)	1989	3
Nigeria	National Space Research and Development Agency (NASRDA)	2006	6
South Africa	South Africa National Space Agency (SANSA)	2010	8
Sudan	National Remote Sensing Center	1977	1
Tunisia	National Mapping and Remote Sensing Center	1988	Scheduled July 2020
Zimbabwe	Zimbabwe National Geospatial and Space Agency	2018	0

The working paper proceeds as follows. The first sections provide an overview of the development of the space sector in China and on the African continent. The second section outlines both bilateral and multilateral space cooperation programs in which African and Chinese counterparts are involved and presents findings on space cooperation from the two country cases of Nigeria and Algeria.

SPACE DEVELOPMENT IN CHINA & AFRICA

CHINA

CHINA'S NATIONAL SPACE ADMINISTRATION (CNSA) was formed in 1993 as an outgrowth of the Number Five Research Academy of the Ministry of National Defense. The Ministry had been established in 1949 by the newly formed People's Republic of China, in the shadow of the US detonation of nuclear weapons in Japan and on Pacific Islands. This geopolitical context helps explain why the Academy's first mandate was to develop nuclear weapons and ballistic missiles in close collaboration with the former USSR from 1950-57. After the Sino-Soviet split in 1957, China's planners relied heavily on scholars educated overseas to advance space and nuclear weapons capability within the Ministry of Defense.[15]

Since Deng Xiaoping's 1978 reforms, China's space institutions have been restructured. In 1988, the central government created the Ministry of Astronautics to oversee space program development. The Ministry was dissolved in 1993 with the formation of two distinct state-owned enterprises: CNSA, which is responsible for carrying out China's international space obligations, and the China Aerospace Science and Industry Corporation (CASC), which is the primary contractor for CNSA. The primary contractor for overseas satellite agreements, the China Great Wall Industry Corporation (CGWIC), is a commercial firm and international platform for CASC. CNSA has also cultivated extensive international partnerships and supported private-sector spin-offs.

Although China's space agency is often discussed as a wholly state-owned and state-run organization, it behaves like other major space agencies by working with private contractors in procurement and engaging in competitive bidding processes. Foremost among these is the CGWIC, which is responsible for commercial launch services, satellite systems, and international space technology cooperation. Over the past three decades, CGWIC has won dozens of contracts to build satellites for space programs across the world, particularly in countries with more recent or smaller space programs. CGWIC often sub-contracts with the China Academy of Space Technology, the China Academy of Launch Vehicle Technology, and the China Satellite Launch and Tracking Control General the way NASA might contract with Boeing or Lockheed Martin, who might then subcontract to smaller companies specialized in specific components required to fulfill the order. As their respective names suggest, each is responsible for a different component of satellite design, development, construction, launch, and operation.

Since 1990, China's Long March rockets have been launching satellite payloads for international partners, including private firms, universities, and national space programs. China launched Nigeria's first communications satellite in 2007 and a second in 2011. Moreover, China launched Algeria's first communication satellite in 2017, as well as the first satellites for Ethiopia and Sudan in 2019. Each of these contracts was won through a competitive bidding process. China's firms do not always win. For example, Ghana contracted with SpaceX (US) to launch its first satellite in

2017, while Russia's space agency launched a satellite for Angola that same year, and Japan launched satellites for Rwanda and Egypt in 2019.

AFRICAN COUNTRIES

MOST SPACE RELATED ACTIVITY OCCURRING IN AFRICA is driven by Africans.[16] Several African countries launched national and multilateral space science and technology initiatives in the mid-twentieth century. Many of their trajectories were influenced by multiple domestic and international political factors. Often this is attributed to changing loyalties following the end of the Cold War, or more frequently, to misallocated investments due to conflict or corruption. While these are possible explanations, preliminary analysis suggests that the oil shocks of the 1970s and debt crises of the 1980s had a more decisive effect on interrupting the advancement of space science in the Global South. During the so-called "Lost Decade" of the 1980s, no new space agencies were established in Latin America.[17] On the African continent, no new space agencies were established between 1971 and 1987, which suggests that the debt-driven development and structural adjustment programs widely implemented across sub-Saharan Africa during this period were negatively associated with the advancement of space science and technology in loan-recipient countries.[18]

Although China's technological engagement with developing country partners tends to receive the majority of attention in Anglophone media and policy discourse, it is important to place China-Africa space partnerships in context. The primary drivers of space science, technology, and policy development in Africa are African scientists and officials who strategically leverage international partnerships to fulfill domestic space mandates. Therefore, space technology development on the African continent is best characterized as a complex mosaic comprised of diverse actors, country-specific investment patterns, and robust public-private activity. Echoing space advocates in newly-independent nations during the heyday of the Non-Aligned Movement, the African Union Agenda 2063 elaborated a Continental Space Policy, which states that "Outer space is of critical importance to the development of Africa in all fields: agriculture, disaster management, remote sensing, climate forecast, banking and finance, as well as defense and security. Africa's access to space technology products is no longer a matter of luxury [...]".[19] With this shift in the perception of space technology from luxury to critical infrastructure, there is also an emerging network of young professionals, both scientifically and entrepreneurially minded, who are building peer networks globally and pursuing capital from outside the continent.[20]

Between 1998 and January 2020, eleven African countries, eight of which are in sub-Saharan Africa, launched a total of forty-two satellites (see Tables 2a and 2b). The countries include Algeria, Angola, Egypt, Ethiopia, Ghana, Kenya, Morocco, Nigeria, Rwanda, South Africa, and Sudan. Additionally, multilateral African institutions jointly funded three regional communications satellites. More than half of these satellites were launched in the last five years, indicating an acceleration of space-related activity. The satellite applications reflect the domestic development priorities they are meant to

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serve: Earth observation, communications satellites, technology demonstration, scientific experiments, educational projects, and military radar. In contrast to space programs in the US, China, and European Union, most African space programs do not prioritize military applications, human spaceflight, or space tourism. Although only eighteen of the forty-two satellites were built by African engineers, with the others being constructed by companies that won competitive bidding processes, ninety percent of all financing was reported to come from African sources. In addition to the CGWIC, a range of other corporations, such as Airbus Defense and Space (France), RSC Energia (Russia), Surrey Satellite Technology Ltd (UK), and Thales Alenia Space (France), have won contracts to build satellites for African space programs. As of mid-2019, approximately 8,500 people were employed in the space sector in Africa; of these, approximately 2,000 were in the commercial space sector.[21]

The national budgets for these space programs differ significantly, as does their position within the respective governments' institutional landscapes. The majority of space programs are located under science, technology, or education ministries (or equivalent), which shapes the nature of bilateral and multilateral engagement undertaken by the respective countries. The national space agencies are part of larger networks of international aerospace and astronomical societies, as well as hundreds of university departments, meteorological stations, telecommunications companies, navigation and aviation authorities, and geographic research and monitoring centers on the continent, each of which have their own unique regional and international engagements.

For example, the Global Monitoring for Environment and Security in Africa program is a joint EU-Africa program which provides earth observation data to EU member states, forty-five African countries, and more than 120 African institutions, several of which have regional centers to process and disseminate data. In addition, there is robust private sector and start-up activity concentrated in major cities, characterized by hackathons, innovation challenges, maker spaces, start-up labs, and competitive grants programs, most of which are funded by African sources. These are enriched by outreach events by organizations from outside of Africa, such as NASA's International Space Apps Challenge, which was hosted at the Pan-African Polytechnic Institute in Dakar, Senegal, in October 2018.[22] There is also sustained and dynamic space-related activity with United Nations entities, such as the Food and Agriculture Organization, the Office for Outer Space Affairs, the Space Generation Advisory Council, and the Agenda 2030 Sustainable Development Goals, to name a few.

There are currently no operational launch facilities on the African continent. Several were built in the mid-twentieth century by former colonial governments but are no longer functional. Since 1998, Africa's satellites have been launched from facilities in French Guiana (10), Russia (7), the US (7), China (6), Kazakhstan (5), India (4), Japan (2), and Ukraine (1).

BILATERAL AGREEMENTS WITH CHINA

THIS SECTION PROVIDES AN OVERVIEW AND CONTEXTUALIZATION of bilateral agreements between African countries and China, and reviews two illustrative country cases: Nigeria and Algeria. China has built and launched satellites for Nigeria, Algeria, Sudan, and Ethiopia. It is the fourth largest recipient of satellite contracts from African countries, and the third largest recipient of launch contracts.[23] As of 2019, sixty percent of Africa's satellites were built by foreign entities, but the proportion is expected to diminish as African entities increase indigenous capacity. South Africa is the largest producer of satellites on the continent, with growing public and private sector space technology capacity. Both Nigeria and Algeria's space agencies have developed domestic satellite production and testing facilities, and Ethiopia's Space Science and Technology Institute has engaged in a joint venture with France's ArianeGroup to develop satellite assembly, integration, and testing facilities in Addis Ababa.[24]

This trend is by design. International satellite partnerships undertaken on the part of African space programs proceed with the proviso that the transfer of know-how and technology is a cornerstone of the agreement. Using commercial off-the-shelf technology and focusing on specific missions accelerates the development process, providing cheaper and faster access to space. The "Learning by Doing" approach entails sending teams of African scientists and engineers to the contracting party to work on site for the duration of the design, construction, and test phases. This accomplishes technology transfer and capacity building goals for African space programs.[25] In some cases, this approach has preceded the development of national space programs. For example, the Rwandan Utilities Regulatory Authority, which is not a space agency, signed an agreement to send six Rwandan engineers to Tokyo University to develop the RwaSat-1 cube satellite.[26] The stated purpose of RwaSat-1 is to enable the country to collect remote sensing data from low earth orbit in order to monitor progress toward the 2030 Sustainable Development Goals.[27] Japan launched RwaSat-1 in December 2019.

It must also be noted that since the 1960s, China's government has provided scholarships to students from African countries to complete undergraduate and graduate education in China. These comprehensive programs have provided transportation, housing, medical, and living expenses principally (though not exclusively) for science and engineering students and their families to relocate to China for the duration of the program of study. In 2018, President Xi Jinping announced that an additional 50,000 scholarships and 50,000 training opportunities would be awarded to African students and researchers over the following three years, increasing both educational and training programs by more than half.[28] Each year, between four and five hundred thousand international students study in China, with over 80,000 coming from African countries.[29] This provides an important legacy of human capital development and diplomatic engagement between China and African partner states that is now several generations old.

Table 2a and 2b show the range of engagements between African institutions, by country, and Chinese entities, while Table 3 shows multilateral engagements.

Table 2a: African China Space-Related Engagements, by Country

Country	Space or Space-related Agency	Founded	Satellites Launched	Bilateral Space Partnership with China
Algeria	Algerian Space Agency (ASAL)	2003	6	AlComSat-1 designed, built, and launched by CAST, CGWIC, CSLTCG, CALVT
Angola	National Space Programme Management Office	2013	1	Delegate visit from CGWIC in September 2019
Côte d'Ivoire	Ministry of Telecommunications	n.d.	Scheduled mid-2020	CGWIC lost satellite contract to France's Airbus Defense and Space in 2018
Democratic Republic of Congo	National Satellite Telecommunications Network (Renatelsate)	1991	0	Contracted with CAST to build and launch CongoSat-1 in 2012
Egypt	Egypt Space Agency	2018	9	CNSA grants US$ 23 million (2016), US$ 45 million (2018), and US$ 72 million for EgyptSat program; over 1,500 Chinese IT and telecommunications companies in Egypt
Ethiopia	Ethiopian Space Science and Technology Institute (ESSTI)	2016	1	ETRSS-1 contracted with CGWIC in 2018, launched 2019. Contracted with China HEAD Aerospace Technology Co. to build ground receiving station in Addis Ababa; 2019 agreement with Chinese Rocket Company to jointly build a communications satellite
Gabon	L'agence Gabonaise d'Etudes et d'Observations Spatiales (AGEOS)	2007	0	Receives satellite imagery and capacity training from joining Brazil-China CBERS for Africa initiative
Ghana	Ghana Space Science and Technology Centre (GSSTC)	2011	1	In talks with China Development Bank for financing and CNSA for technical advice for future satellite programs
Kenya	Kenya Space Agency	2017	1	In talks with CNSA for assistance developing satellites; Machako University physics experiment selected to be conducted on China Space Station
Libya	Libya Center for Remote Sensing and Space Science (LCRSSS)	1989	0	None found
Morocco	The Royal Center for Remote Sensing Space (CRTS)	1989	3	None found

Table 2b: African China Space-Related Engagements, by Country

Country	Space or Space-related Agency	Founded	Satellites Launched	Bilateral Space Partnership with China
Namibia	Namibian Institute of Space Technology at the Namibian University of Science and Technology	n.d.	0	Jointly owned China Telemetry, Tracking, and Command Station built in Swakopmund became operational in 2001; hosted Chinese astronauts' visit in 2010 and 2019
Nigeria	National Space Research and Development Agency (NASRDA)	2006	6	NigComSat-1, NigComSat-1R designed, manufactured, and launched by CGWIC. Contracted 2004 and 2009, launched 2007 and 2011, respectively. People's Insurance Company of China provided insurance for NigComSat-1
Rwanda	Rwandan Utilities Regulatory Authority	n.d.	1	None found
Saudi Arabia	Saudi Space Commission	2018	16	Firm in King Abdulaziz City for Science and Technology developed a camera for China's lunar orbiter satellite Longqiao-2; data-sharing MOU signed March 2017
Senegal	Ministry for Higher Education, Research, and Innovation	n.d.	Scheduled 2021	None found
South Africa	South Africa National Space Agency (SANSA)	2010	8	Developed components for China's Chang-e lunar rover, which landed on the moon in January 2019; Private firm NewSpace Systems, Ltd produces satellite components for retailers in China, India, Japan, Netherlands and the US
Sudan	National Remote Sensing Center	1977	1	SRSS-1 built by Shenzhen Aerospace Oriental Red Sea Satellite Co, and launched by China's Long March 4B rocket in November 2019
Tunisia	National Mapping and Remote Sensing Center	1988	Scheduled July 2020	Ground receiving station for BeiDou satellite navigation system opened near Tunis in April 2018; jointly operated by CNSA and Arab Information and Communication Technology Organization
Zimbabwe	Zimbabwe National Geospatial and Space Agency	2018	0	None found

Table 3: Multilateral China Space-Related Engagements

Organization	Space or Space-related Agency	Founded	Satellites Launched	Space Partnership with China
African Union	African Space Agency	2018	3	In talks with China Development Bank for potential financing
Arab League	Arab Satellite Communications (ArabSat)	1976	13	Broadcasts the Arabic-language edition of China Global Television Network

NIGERIA

MOST RESEARCH ON CHINA-NIGERIA RELATIONS focuses on energy, infrastructure, and military sectors, which is somewhat surprising given the importance of space cooperation for both parties. Among African nations, Nigeria has the most extensive satellite development involvement with China. The two governments established diplomatic relations in 1971. Since the turn of the millennium, Chinese aid, loans, and investments in Nigeria have increased precipitously. In 2006, Nigeria became the first African country to sign a Strategic Partnership Agreement with China's Ministry of Foreign Affairs.[30] Moreover, Nigeria has been among China's largest trading partners in Africa over the past decade. There are tens of thousands of members of the Chinese and Nigerian diasporas living in each other's countries.[31]

Nigeria's National Space Development and Research Agency (NASRDA) was established in 2001. In December 2004, the Nigerian government contracted with CGWIC to build the country's second satellite, NigComSat-1. In 2006, Nigeria's Ministry of Finance signed an agreement with the China Export and Import Bank for US$ 200 million in preferential buyer's credit to help fund the project. Nigerian scientists and engineers traveled to China to receive training and participate in satellite design and construction.[32] In anticipation of the launch of Nigeria's—and Africa's—first communications satellite, NigComSat-1, a private spin-off from NASRDA was incorporated in 2006 to provide fixed satellite services to much of Africa and Italy. The satellite launched from Xichang Satellite Launch Center in Sichuan, China, in May 2007. Beginning in mid-2008, technical errors in its solar arrays caused the satellite to fail, and it was de-orbited in November 2008. However, the satellite's insurance funded a second contract with CGWIC to build the replacement satellite, NigComSat-1R. Some technical improvements were made to address the issues with the previous version, and NigComSat-1R launched again from Xichang in 2011.

Although Nigeria's subsequent satellite contracts have been with the UK and Japan, technical cooperation with China has continued. In 2016, China's Ministry of Science and Technology offered to build a ground receiving station to enable Nigerian scientists to collect data from the China-Brazil Earth Resources Satellite (CBERS) array. As of this writing, no further plans have been disclosed. However, the agreement under which China would extend 700 government-funded scholarships and technical training

to 1,000 space engineers has progressed. As of August 2019, over 500 Nigerian students have received such scholarships to study in China.

Nigeria-China space cooperation illustrates the nature of Africa-China cooperation more generally. Nigeria has multiple space partners. Although CGWIC won a contract for Nigeria's communications satellite, this did not lock Nigeria into an exclusive relationship with Chinese agencies. Nor is this a case of Chinese charity. When NigComSat-1 failed, insurance money paid for the construction and launch of NigComSat-1R. For China's part, the collaboration was an important milestone for CGWIC. This was the first time a Chinese firm provided in-orbit delivery to an international client. Prior to this, China's international space contracts consisted primarily of launch agreements.

The primary drivers of space science, technology, and policy development in Africa are African scientists and officials who strategically leverage international partnerships to fulfill domestic space mandates. Therefore, space technology development on the African continent is best characterized as a complex mosaic comprised of diverse actors, country-specific investment patterns, and robust public-private activity.

ALGERIA

IN THE CASE OF ALGERIA, SPACE COOPERATION WITH CHINA is a comparatively smaller dimension of an expansive bilateral technical, economic, cultural, and policy cooperation portfolio. Algeria and China have been allies since the early 1950s. The young People's Republic of China provided military support to Algeria in the country's war for independence from France, and China was the first non-Arab country to establish full diplomatic ties with the Algerian Provisional Government in 1958. In the face of an international boycott, the Algerian government mobilized the support of other African countries for China when the People's Republic hosted the 2008 Olympic Games. The two countries foster robust student exchanges, providing scholarships to Chinese and Algerian students to study in each other's countries.[33]

The Algerian Space Agency (ASAL) was established in 2002. The governments of Algeria and China signed a Memorandum of Understanding (MOU) to cooperate in outer space development in 2007, established a bilateral Comprehensive Strategic Partnership in 2014, and signed an MOU to place their bilateral cooperation under the framework of the BRI in September 2018. But while Chinese firms are major players in Algeria's construction and energy sectors, this is not the case in the space sector. In addition to China, the Algerian government has bilateral space cooperation with Argentina, France, India, Russia, Syria, Ukraine, the UK, and the US, and is a founding member of ArabSat (see page 17). ASAL's space partnerships are designed to facilitate technology and knowledge transfer to support the growth of indigenous capacity.

In December 2013, the Algerian government ordered AlComSat-1, a geostationary communications satellite from CGWIC. Financed entirely by ASAL, this was Algeria's fifth satellite and the only one ordered from China to date. The others had been developed and launched with European, Russian, and Indian partners, and involved the training of Algerian scientists and engineers in post-graduate studies during the design and construction phase of the satellite, with programs continuing to date. The AlComSat-1 contract included the design, manufacture, test, launch, and construction of associated ground infrastructure necessary for satellite operation.[34] CGWIG sub-contracted parts of the project to the China Academy of Space Technology, the China

Academy of Launch Vehicle Technology, and the China Satellite Launch and Tracking Control General. Following its successful placement in geostationary orbit by China's Long March-3B rocket from Xichang Satellite Launch Center, ASAL assumed control of in-orbit operation, management, and applications from ground stations in Algeria.[35] Alcomsat-1 is used for broadcasting, emergency communications, remote education, and satellite broadband.

There is much about Algeria, and Algeria-China relations, that cannot be generalized to the rest of the continent. Nevertheless, the structure of bilateral space relations is illustrative of both countries' respective space development strategies. Consistent with Algeria's *15-year National Space Programme* (2005 – 2020), satellite contracts with overseas partners were designed to support the growth of Algerian space infrastructure and human capital while preserving and promoting Algerian sovereignty. Algeria's contract with China did not involve any grants or loans; as with other Chinese construction projects in the country, the Algerian government paid in full for satellite development and launch. The training component appears to have been more modest than previous training agreements with European counterparts, although specific numbers of engineers and scientists trained are not published and could not be attained from meetings with Algerian counterparts in November 2019.[36] For China's part, the commercial relationship follows a now familiar pattern: CGWIC acts as the international arm of CASC, and subcontracts components of the assembly and launch process to an array of private and state-owned Chinese firms in order to support the increasing specialization and diversification of China's space sector.

MULTILATERAL SPACE COOPERATION

ALTHOUGH CHINESE AID, INVESTMENT, LOANS, AND PROJECTS in Africa tend to receive far more media exposure compared to other donors' and investors' interventions, grounded research has shown that China's activities in Africa take place within a complex landscape of bilateral and multilateral relations, several of which began in the mid-twentieth century.[37] This is also true for space cooperation. African protagonists were instrumental in constructing the 1967 Outer Space Treaty and subsequent international agreements that have provided the framework for the largely peaceful development of space science and technology over the last sixty years. Cooperation with a diversity of partners characterizes the international strategies of space programs in African countries, of which China's firms and space agencies are one part. This section outlines eight major multilateral space cooperation initiatives in which African and Chinese space agencies are engaged.

These multilateral initiatives create conditions for robust science diplomacy, which can seed additional bilateral engagements. In addition to their central contributions to advancing global earth and space sciences, these multilateral initiatives provide a meeting ground for scientists, policymakers, and the publics of participating countries. As such, they are advancing the science, education, and

technology essential for achieving development goals, while also forging connections across diverse societies.

International satellite partnerships undertaken on the part of African space programs proceed with the proviso that the transfer of know-how and technology is a cornerstone of the agreement. Using commercial off-the-shelf technology and focusing on specific missions accelerates the development process providing cheaper and faster access to space.

1. THE ASIA-PACIFIC SPACE COOPERATION ORGANIZATION (APSCO)

FOUNDED IN BEIJING IN 2008 WITH SEVEN MEMBER states from Asia and Latin America, the purpose of APSCO is to foster space research, development, data-sharing, and technology transfer among member states. In 2015, APSCO issued the Beijing Declaration, which realigned the priorities of the organization to use "the Belt and Road Initiative for facilitating space capabilities building of the Asia Pacific countries."[38] Algeria, South Africa, and Tunisia, *inter alia*, have sent representatives to participate in forums and research workshops. South Africa's National Space Agency (SANSA) has been most actively pursuing affiliation in order to accelerate its development of advanced satellite capabilities. APSCO delegations have also made regular research visits to SANSA headquarters in South Africa.[39]

2. THE BRICS REMOTE SENSING SATELLITE CONSTELLATION AGREEMENT

ON OCTOBER 31, 2016, THE HEADS OF SPACE AGENCIES of the BRICS member states (Brazil, Russia, India, China, and South Africa) met in Zhuhai, China, to discuss the construction of joint satellite arrays for Earth observation and remote sensing.[40] Less than a year later, on July 3, 2017, the parties convened in Haikou, China, to draft the BRICS Remote Sensing Satellite Constellation Agreement. A technical meeting in Brasília, Brazil, followed on September 18–20, 2017, which served as the first official BRICS Remote Sensing Satellite Forum. At the November 2019 forum in Brasília, as the formation of the Space Force was being debated in the US Congress, the leaders of the five countries proposed a legally-binding agreement that would prevent the placement of weapons in outer space.[41] Among many other applications, the coordination of a BRICS remote sensing network will provide the BRICS-founded New Development Bank with the data and imagery that is critical to development project planning, implementation, and monitoring. South Africa currently does not have an Earth observation satellite larger than a nanosat (a satellite between 1 and 10 kg), but SANSA is responsible for aggregating Earth observation data for southern African countries. It is part of the International Space Environmental Service and monitors weather for the southern African region. At present, it is contributing terrestrial infrastructure to the effort, with plans to expand its satellite capabilities in the next decade.[42]

3. THE CHINA-BRAZIL EARTH RESOURCE SATELLITE (CBERS) FOR AFRICA PROGRAM

HAILED AS A MODEL OF SOUTH-SOUTH SPACE COOPERATION and an inspiration for the BRICS Remote Sensing Satellite Constellation Agreement, the CBERS program

began as a joint venture between Brazil's National Space Research Institute (*Instituto Nacional de Pesquisas Espaciais – INPE*) and China's Academy of Space Technology in 1988. The CBERS for Africa Program grew out of the thirty-year bilateral collaboration between China and Brazil. The decision to provide free imagery to Africa from Brazil's cameras on board the CBERS craft in 2007 made Brazil the world's largest distributor of free satellite imagery to Africa at the time.[43] The program began by making CBERS images available for free to environmental ministries and organizations in Africa, accompanied by the necessary software to access the satellite data. The first ground station to receive the data was in South Africa in 2007, followed by stations in Kenya and the Canary Islands in 2008.[44]

This program represented the first time in the history of orbital remote sensing that multi-spectral high resolution data was downlinked to foreign ground stations without licensing fees, which meant that satellite imagery was distributed to end users in Africa immediately upon processing.[45] In 2011, China's Ministry of Science and Technology incorporated Phase II of the construction of South Africa Hartebeetshoek's satellite ground receiving station into its portfolio of international scientific and technological cooperation projects, which was completed in 2015. The station provides real-time receiving, processing, and distribution of CBERS-4 Satellite data for thirteen southern African countries.[46] To further the impact of this program, Brazil's and China's space programs offered training to partners in several African countries, exemplified by Brazil's Capacitree program (see below). The sixth and most recent CBERS satellite was launched from Taiyuan Satellite Launch Center on December 20, 2019.

African protagonists were instrumental in constructing the 1967 Outer Space Treaty and subsequent international agreements that have provided the framework for the largely peaceful development of space science and technology over the last sixty years.

4. CAPACITREE

THE CBERS FOR AFRICA PROGRAM COMPLEMENTS BRAZIL'S INPE Capacitree program, which trains technicians in partner states with tropical forest and savannah biomes to process remote sensing satellite data for environment and development monitoring.[47] Brazil's INPE has provided training for African scientists and technicians to use Earth observation data and remote sensing technologies for forest monitoring from seventeen African countries—Algeria, Burkina Faso, Burundi, Cameroon, the Central African Republic, Chad, the Democratic Republic of the Congo, Equatorial Guinea, Gabon, Ghana, Guinea, Kenya, Morocco, São Tomé e Principe, South Africa, Tanzania, Tunisia, and Zambia. Capacitree is supported by the United Nations Food and Agriculture Organization, the Japan International Cooperation Agency, the Caribbean Community, the Amazon Cooperation Treaty Organization, and the Inter-American Development Bank.[48]

5. THE ARAB SATELLITE COMMUNICATIONS ORGANIZATION (ARABSAT)

FOUNDED IN 1976 AND HEADQUARTERED IN RIYADH, Saudi Arabia, ArabSat receives its US$ 500 million annual operating capital from all twenty-two Arab states, except the

Comoros Islands. Its satellite control stations are located in Riyadh, Saudi Arabia and Tunis, Tunisia. The array provides entertainment and communications services to eighty countries in the Middle East, North Africa, and Europe. The organization owns and operates seven satellites located in geostationary orbit. The first six satellites were built by European contractors and launched by French and US rockets.[49] The Arabsat-6A was built by Lockheed Martin and was the first successful commercial launch by the SpaceX Falcon Heavy Rocket from Kennedy Space Center in April 2019.

In March 2019, ten member states—Algeria, Bahrain, Egypt, Jordan, Kuwait, Lebanon, Morocco, Saudi Arabia, Sudan, and UAE—launched the Arab Space Cooperation Group headquartered in the United Arab Emirates. It is envisioned as a precursor to an Arab Space Agency, modeled after the European Space Agency. The group is currently developing an Earth observation and environmental monitoring satellite, to be launched in 2023.[50] ArabSat has provided a platform through which individual Arab states, such as Saudi Arabia, cooperate with China and other countries in satellite component development, construction, and data-sharing. For example, a Saudi-developed camera was installed on China's lunar orbiter satellite Longqiao-2, which captured images of the lunar surface and provided lunar data to both countries.[51]

In addition to their central contributions to advancing global earth and space sciences, these multilateral initiatives provide a meeting ground for scientists, policymakers, and the publics of participating countries. As such, they are advancing the science, education, and technology essential for achieving development goals, while also forging connections across diverse societies.

6. THE CHINA-ARAB STATES BEIDOU GLOBAL SATELLITE NAVIGATION SYSTEM STATION (BDS)

CHINA'S BEIDOU NAVIGATION SATELLITE SYSTEM (BDS) consists of three generations of satellite constellations. The first three-satellite constellation provided navigation services to China and neighboring states between 2000 and 2012. This was considered important for China's security purposes to have an indigenous navigation system and to achieve independence from the US-controlled GPS array. The second constellation of ten satellites was launched in 2011 and 2012 to provide navigation services to the Asia-Pacific region. In 2015, CNSA began building up the third generation of thirty-five ultra-high resolution satellites to provide global coverage and to present BRI partner states with an alternative to the United States' GPS system or Europe's Galileo satellite navigation system.[52] In 2016, the Arab League unanimously voted to establish the first overseas processing station for BDS in Tunisia.[53] This arrangement leverages and expands upon existing ArabSat infrastructure in Tunis.

7. DISASTER MONITORING CONSTELLATION (DMC)

AN INTERNATIONAL DISASTER MONITORING CONSTELLATION was initially proposed at the Forty-Seventh International Astronautical Federation Conference held in Beijing in 1996 and led by Surrey Satellite Technology Limited (UK).[54] Algeria, Nigeria, Turkey, the UK, and China joined the DMC, which launched satellites from 2002 to 2005. The Constellation was recommended by the United Nations as part of an effort to increase coordination among space agencies to better monitor natural

disasters and support relief planning efforts. The goal was to achieve daily repeat imagery anywhere in the world transmitted to a variety of ground stations.[55] Algeria's contribution to the constellation, Alsat-1, was developed through a collaboration between the UK's Surrey Satellite Technology Limited and the Algerian National Space Technology Centre. The arrangement included training for Algerian engineers in the UK. The first DMC satellite, Alsat-1, launched in November 2002 from the Plesetsk Cosmodrome in Russia. CNSA launched its indigenously developed Beijing-1 in 2005.[56]

8. SQUARE KILOMETER ARRAY (SKA)

THE SKA IS AN INTERNATIONAL ASTRONOMY INITIATIVE headquartered at the Jodrell Bank Observatory, near Manchester, UK. It was established in December 2011 with the goal to build the world's largest radio telescope, eventually measuring over a square kilometer (one million square meters), to be completed in South Africa and Australia with later expansions into other African countries. Other SKA members include Canada, China, France, Germany, India, Italy, the Netherlands, New Zealand, Spain, Sweden, and the UK.[57] South Africa's government has assumed responsibility for developing the MeerKAT telescope as a run-up to SKA, which became operational in July 2018 and is now the world's most powerful telescope of its kind. Second is the National Astronomical Observatories of China, which operates the world's largest single dish radio telescope, the five-hundred-meter Aperture Spherical radio Telescope.

China's Fifty-Fourth Institute of China Electronics Technology Group Corporation has been leading the international effort to design the SKA dish with principle partners from South Africa, Canada, France, Germany, Italy, Sweden, and the UK.[58] Since 2005, South Africa's African SKA Human Capital Development Program has awarded more than 1,000 grants to advance studies in astronomy and engineering in Kenya, Madagascar, Mauritius, and Mozambique. African SKA partner countries also include Botswana, Ghana, Namibia, and Zambia.[59] South Africa is perhaps unique amongst African nations for an explicit focus on astronomy and its commitment to advancing its data management system specifically for astronomy purposes.[60]

CONCLUSION

MOST SPACE-RELATED ACTIVITY HAPPENING IN AFRICA is driven by Africans. The roles of China's institutions in the space development programs of African countries are diversified and important, but they remain comparatively smaller than those of other international partnerships maintained by African space agencies. Still, China's successes in providing relatively low-cost, reliable, and comprehensive satellites to African counterparts have brought about important milestones for both sides. As the current generation of African space scientists, social scientists, and entrepreneurs continue to grow space capacities on the continent, social science research concerning the African space community should likewise continue to mature in order to inform good policies that promote global collaboration and exchange in space sciences and

technologies. Potentially productive research areas include global data sharing politics and practice, the domestic determinants of national space priorities, and the impact of growing space capacity on major domestic and international governance questions. ★

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