SOUTH CHINA SEA MILITARY CAPABILITY SERIES

A Survey of Technologies and Capabilities on China's Military Outposts in the South China Sea

UNDERSEA FIBER-OPTIC CABLE AND SATELLITE COMMUNICATIONS

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NSAD-R-20-046
July 2020

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Introduction

This military capability (MILCAP) study focuses on undersea fiber-optic cable and satellite communications (SATCOM) capabilities on seven Chinese island-reef outposts in the South China Sea (SCS). These SCS MILCAP studies provide a survey of military technologies and systems on Chinese-claimed island-reefs in the Spratly Islands approximately 1,300 kilometers (700 nautical miles) south of Hong Kong (see Figure 1). These Chinese outposts have become significant People's Liberation Army (PLA) bases that will enhance future Chinese military operations in the SCS, an area where Beijing has disputed territorial claims (see Appendix B). The SCS MILCAP series highlights a PLA informationized warfare strategy to gain and maintain information control in a military conflict.

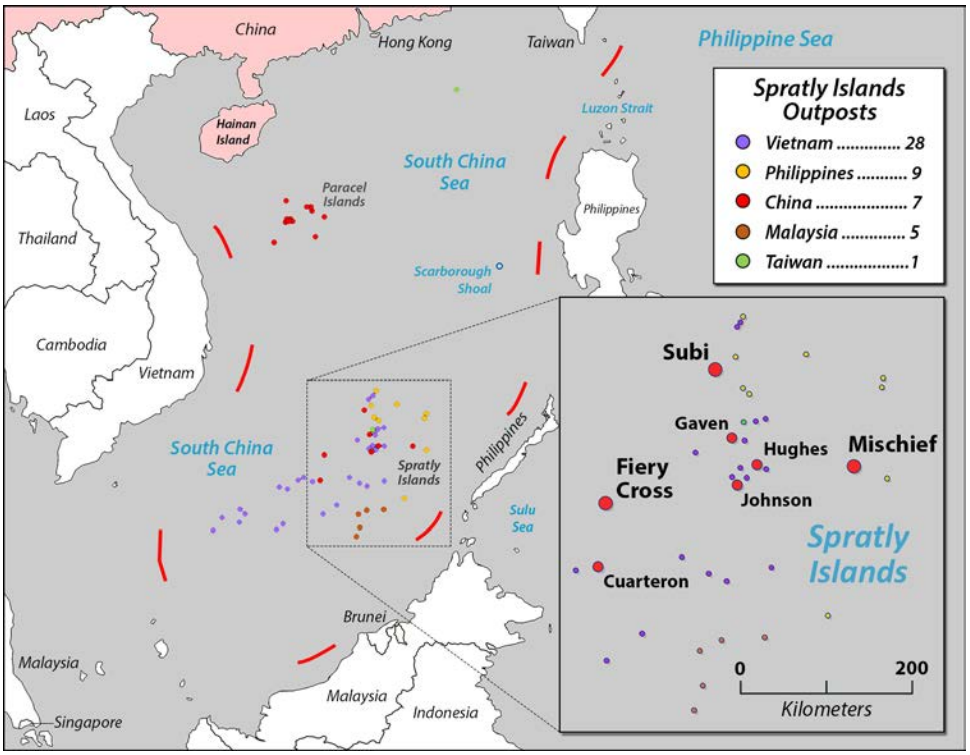


Figure 1. SCS Occupied Features

Chinese SCS outpost long-range communications were significantly enhanced in 2017 by an undersea fiber-optic cable link with the Chinese mainland. The undersea fiber-optic communications network joined a robust SATCOM capability as well as high-frequency (HF) communications that, together, provide redundant, high-capacity, long-haul connectivity for China's SCS island-reefs. Overview graphics of all capabilities noted on major outposts appear in Appendix C.

Undersea Fiber-Optic Cable, 海底光缆

The primary communication means for China's SCS outposts is likely an undersea fiber-optic cable network. An undersea fiber-optic network provides secure, reliable, high-capacity communications and data exchange among China's seven SCS outposts, as well as the Paracel Islands and the Chinese mainland. Integrating undersea fiber-optic cable with other means of communication is in keeping with the PLA's strategy to establish and maintain a significant information advantage in any SCS conflict. Even if fiber-optic connectivity with the mainland were lost, high-data rate fiber-optic communications among the island-reefs allows the PLA to coordinate operations and exchange radar or other intelligence, surveillance, and reconnaissance (ISR) data between outposts and "heal" damaged networks using SATCOM or other means.

In June 2017, government-owned China Telecom announced that it connected China's three major SCS reefs—Fiery Cross, Subi, and Mischief Reefs—to a submarine fiber-optic cable network. According to the news release, Fiery Cross Reef was the first outpost connected to the mainland by fiber-optic cable in September 2016. All seven Chinese-held island-reefs in the southern SCS were reportedly connected to the underwater cable network by the end of 2017.[1] The China Telecom fiber-optic cable network in the SCS serves the communications needs for civil government activities, including air traffic control, China coast guard operations, government logistics, and support to the fishing industry. It also supports cell phone service for military and civilian personnel on the island-reefs and in surrounding waters.

Reports about the civilian communications infrastructure provides some indication of the magnitude of the improvements gained by SCS installations from undersea fiber-optic cable. In 2016, the reported SATCOM bandwidth available on Fiery Cross Reef for civilian purposes was 10 megabits per second (Mbps).[2] In January 2018, the PLA Navy announced that under a new civil–military agreement, the civil communication bandwidth enabled by undersea fiber-optic cables to the major island-reef outposts would increase to 622 Mbps. The minor outposts, such as Cuarteron, would be upgraded from 4 Mbps satellite-speed communications to 155

[1] Wang Bin and Wu Qi, "中国电信在南沙群岛开通多个光缆 4G 基站提升通信服务质量" [China Telecom Opens Multiple Fiber 4G Base Stations in the Nansha [Spratly] Islands to Improve Communication Service Quality], 中国新闻网 [China News Network], June 12, 2017, http://www.chinanews.com/cj/2017/06-12/8248316.shtml.

[2] "南沙群岛建成卫星通信 4G 基站" [Nansha [Spratly] Islands Built Satellite Communications 4G Base Station], 科技世界网 [Technology World Network], July 26, 2016, http://www.twwtn.com/detail_216819.htm.

Mbps cable communications. This civilian fiber-optic network expansion was scheduled to be completed by May 2018.[3]

The acknowledgement of a submarine fiber-optic cable network in the SCS indicates that the PLA likely communicates through the civilian network or is connected to a parallel military fiber-optic cable network, part of the military's national defense communications network (NDCN) (国防通讯网). The NDCN's fiber-optic cable backbone (国防光缆) serves as the PLA's primary communications network on the mainland.[4] Normally, the NDCN fiber-optic cable network is physically segregated from the civilian telecommunications network.[5] However, the civilian network may be connected to the military network as a backup should NCDN cables suffer damage in a conflict or natural disaster.[6] Available Chinese sources do not indicate whether the SCS civilian telecommunications network rides on military undersea fiber-optic cable or vice versa or whether China Telecom and the PLA maintain separate undersea fiber-optic cable networks.

The PLA has extensive capabilities to independently install and maintain NDCN fiber-optic cables. The uniformed personnel of the PLA's Strategic Support Force (SSF) are responsible for the majority of the NDCN infrastructure.[7] The PLA Navy appears to have retained responsibility for installing and maintaining undersea fiber-optic cable. In 2003, the PLA established the Submarine Cable Communication Technology

[3] Zhou Qiqing and Li Xiaodong," 这个新春，西南沙岛礁将步入"4G+"时代" [This New Year, Xisha (Paracel) and Nansha (Spratly) Island Reefs will Step into the '4G+' Era], 新华网 [Xinhua Network], January 30, 2018, http://www.xinhuanet.com/mil/2018-01/30/c_129801458.htm. The Xinhua source statement indicates that this article originated in the PLA periodical 当代海军 [Contemporary Navy].

[4] Liu Hui, "借力共护国防光缆" [Leveraging Common Protection of National Defense Optical Cable], 中国国防报 [China National Defense News], March 11, 2016, 4. See also Li Kangle and Liu Tao, "国防通信光缆线路的维护" [Maintenance of Defense Communication Optical Cables], 电子技术与软件工程 [Electronic Technology and Software Engineering], no. 13 (July 10, 2014): 74.

[5] The Chinese military routinely conducts public awareness campaigns about the importance of National Defense Communications Network fiber-optic cable and the consequences for damage by farming or excavation. See, for example, "一不小心挖断国防光缆有啥后果?" [What Are the Consequences for Accidentally Damaging the National Defense Cable?], 壹讀 [One Read], July 19, 2018, https://read01.com/6GaM32g.html#.XWPN4Hl4eUk.

[6] Xie Feng, Li Haiqiang, and Wu Yanmei, "军民互联确保网络无限畅通" [Military and Civilian Interconnection Ensures Unlimited Network Connectivity], 创新广东 [Innovation Guangdong], September 25, 2015, 1, http://digitalpaper.stdaily.com/http_www.kjrb.com/kjrb/images/2015-09/25/12/DefPub2015092512.pdf.

[7] See, for example, this official SSF social media post: Wang Guoyun and Jiang Yi, "厲害了, 我的通信兵!" [Incredible, Our Communications Soldiers!], 微文庫 [Micro Library], July 6, 2017, https://tw.wxwenku.com/d/101262867.

Research Center at the Wuhan PLA Naval University of Engineering. The research center supervises military undersea cable construction and maintenance.[8]

In late 2014, the PLA Navy commissioned a new class of oceangoing cable-laying ship, the 5,000-ton *East Cable 885* (东缆 885).[9] The second ship in the class, *South Cable 233* (南缆 233), was commissioned in 2017.[10] These ships are responsible for installing and maintaining military undersea fiber-optic cables for the PLA.[11]

Satellite Communications, 卫星通信

SATCOM provides a complementary and redundant communications capability to the SCS fiber-optic cable network. SATCOM provides connectivity with the Chinese mainland and among the SCS outposts. Outpost SATCOM also provides communications from the island-reefs to ships, submarines, aircraft, and unmanned systems. Examining the extensive SATCOM infrastructure on the SCS outposts illustrates the premium that the Chinese military places on robust, high-capacity access to information in peacetime and in conflict.

Since 2010, China significantly increased its investment in communications satellites. Now operating over three hundred satellites, China recently overtook Russia with the second most satellites on orbit. The world's leading space-faring nation, the United States, has over nine hundred satellites on orbit. Satellite inventory numbers are rapidly becoming skewed by an international trend toward launching large numbers of small satellites operating in low-Earth orbit (LEO). Mirroring the United States, China is entering the LEO small-satellite market, a move that will likely triple its satellite inventory in the next several years. (See the discussion of LEO satellite constellations in a subsequent section.)

[8] PLA Submarine Cable Communication Technology Research Center, 第四届全国海底光缆通信技术研讨会论文集 [The 4th National Symposium on Submarine Fiber Optic Communication Technology], ed. Yang Ling (Hebei: People's Post and Telecommunications Publishing House, 2017), 1.

[9] "布缆船" [Cable Boat], 新华网 [Xinhua Network], http://www.xinhuanet.com/mil/2016-03/28/c_128838813_12.htm.

[10] "中国海军那些不为人知的军辅船" [The Chinese Navy's Unknown Military Auxiliary Vessels], 兵器知识 [Ordnance Knowledge], June 20, 2017, http://bingqizhishi.1she.com/10387/334337.html.

[11] Zuo Leiand Wang Yalin, "原来我们能互联世界, 全靠深海 '蜘蛛侠' " [It Turns Out We Can Connect the World with the Deep Sea "Spider Man"], 当代海军 [Modern Navy], February 20, 2017, https://chuansongme.com/n/1589148652823.

Geostationary Earth Orbit SATCOM

Communications satellites in geostationary earth orbit (also called geostationary equatorial orbit, or GEO) maintain a constant position relative to the earth from their orbits above the equator. As of mid-2020, the People's Republic of China (including Hong Kong) registered thirty-four communications satellites in geostationary orbit.[12] At least six of these geostationary satellites are probably dedicated military satellites. PLA communications satellites are widely reported to have military designators—the "Fenghuo" series (ChinaSat-1A, 1C) and the "Shentong" series (ChinaSat-20A, 2A, 2C, 2D). The Fenghuo-series satellites likely provide tactical military communications, described as "theater-level C3I (command, control, communications and intelligence)" in the C-band and ultra-high frequencies (UHF). The Shentong-series satellites have been described as "strategic communications" satellites and likely provide steerable Ku-band spot beams. [13] The newest of these military communications satellites, ChinaSat-2D was launched in January 2019.[14]

To meet its SATCOM requirements, the PLA probably relies on significant augmentation from Chinese commercial communications satellites, most of which are government-owned and operated. These include satellites like the experimental Shijian-series, Tiantong-1, and other government-owned ChinaSat-series satellites.

The Chinese government normally describes Shijian-series satellites as technology demonstrators. "Shijian" (实践) translates as "practice." However, many China-space watchers concluded that Shijian-series satellites may be military platforms because of their secretive nature and often-unusual orbits.[15] Shijian-13, recently renamed ChinaSat-16, employs electric propulsion for station-keeping on-orbit and also successfully tested a two-way high-capacity laser communications link with a ground station, both firsts for China. Shijian-13/ChinaSat-16 provides twenty-six Ka-band spot beams with a throughput of 20 gigabits per second (Gpbs). When it launched in

[12] "NSSDCA Master Catalog," NASA, accessed July 1, 2020, https://nssdc.gsfc.nasa.gov/nmc/; and "UCS Satellite Database," Union of Concerned Scientists (UCS), updated April 1, 2020, https://www.ucsusa.org/media/11491.

[13] Roger Cliff, Chad J. R. Ohlandt, and David Yang, *Ready for Takeoff—China's Advancing Aerospace Industry* (Santa Monica: RAND Corp., 2011), 94–95.

[14] Chris Bergin, "Long March 3B Lofts ChinaSat-2D," NASA Spaceflight.com, January 10, 2019, https://www.nasaspaceflight.com/2019/01/long-march-3b-lofts-chinasat-2d/

[15] See, for example, Tomasz Nowakowski, "China Conducts Surprise Launch of Second Shijian-16 Satellite," Spaceflight Insider, June 30, 2016, http://www.spaceflightinsider.com/organizations/china-national-space-administration/china-conducts-surprise-launch-second-shijian-16-satellite/; and Colin Clark, "China Satellite SJ-17, Friendly Wanderer?," Breaking Defense, April 18, 2018, https://breakingdefense.com/2018/04/china-satellite-sj-17-friendly-wanderer/.

2017, this one satellite purportedly offered more data capacity than all of China's other communications satellites combined.[16] For comparison, each US military wideband global SATCOM (WGS) satellite is reported to provide data rates between 2.1 Gbps and 3.6 Gbps.[17] As of 2020, the US company Viasat claimed the highest network capacity for any communications satellite – ViaSat-2 at 260 Gbps.[18]

In December 2019, China launched its Shijian-20 satellite, again describing it as a technology demonstrator. Weighing 8 metric tons, Shijian-20 is the heaviest and most advanced geostationary communications satellite China has on-orbit. Shijian-20 will reportedly be used to develop the next generation of Chinese communications satellites, delivering over 1 terabits per second (Tbps) of bandwidth. Shijian-20 will test communications in the extremely high frequency (EHF) Q/V-bands between 33 and 75 gigahertz (GHz).[19] Both Shijian-13 and Shijian-20 communications satellites could significantly enhance PLA SATCOM availability and data rates in the SCS.

China's Tiantong-1 satellite may also provide the military in the SCS with significant mobile communications capabilities. The Tiantong-1 is a geostationary satellite that is the first in a series of planned Chinese satellites that will provide communications with mobile SATCOM terminals as small as a handset (see Figure 2). The first Tiantong geostationary satellite provides services similar to those of United Kingdom-based Inmarsat. The Tiantong-1 satellite operates in the S-band (2–4 gigahertz) and provides coverage for all of mainland China, the SCS, and the western Pacific Ocean. The Tiantong system operates in conjunction with China Telecom's cellular network on the Chinese mainland and in the SCS.[20] Chinese state-media pundits declared that the Tiantong satellite is principally a civilian system, but it may have military utility

[16] Zou Weirong and Qiu Xuelei, "我国首颗高通量通信卫星实践十三号投入使用" [China's First High-Throughput Communication Satellite Shijian-13 Put into Use], 中国军网 [China Military Online], January 23, 2018, http://www.81.cn/jmywyl/2018-01/23/content_7919022.htm. See also "ChinaSat 16," China Satellite Communications Co., Ltd., last modified May 25, 2017, http://english.csat.spacechina.com/n931903/c1657772/content.html.

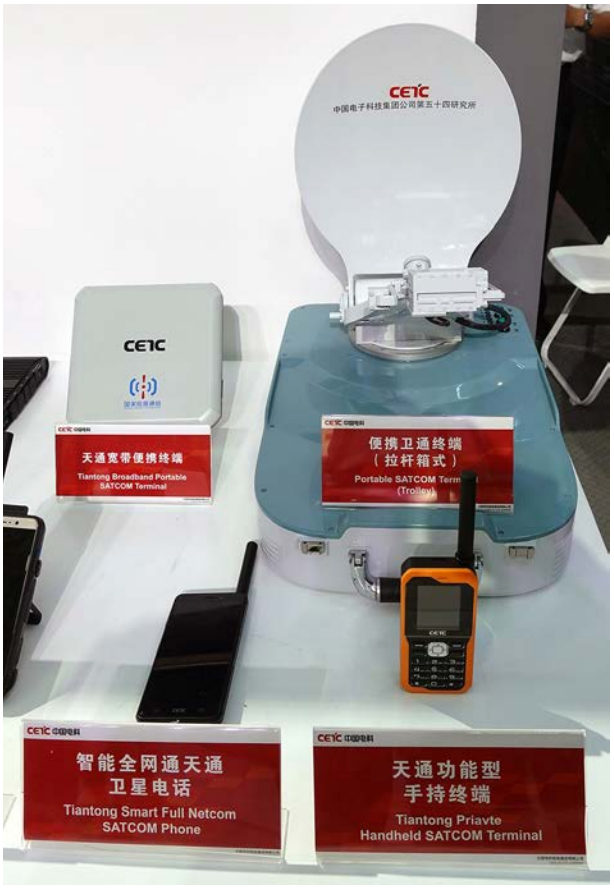
[17] "Wideband Global SATCOM (WGS) Satellites," Aerospace Technology, accessed July 1, 2020, https://www.aerospace-technology.com/projects/wgs-satellite/.

[18] "High-Capacity Satellite System," Viasat, Inc., accessed July 1, 2020, https://www.viasat.com/products/high-capacity-satellites.

[19] Quan Xiaoshu and Yu Fei, "China Launches Heaviest Satellite to Test Key Technologies," *Xinhua*, December 27, 2019, http://www.xinhuanet.com/english/2019-12/27/c_138662080.htm.

[20] Shi Feiyue, "中国自主卫星电话正式放号" [China's Autonomous Satellite Phone Officially Released], 北京商报 [Beijing Business Daily], May 16, 2018, http://www.xinhuanet.com/tech/2018-05/16/c_1122837861.htm.

because it is the first telecommunications satellite controlled by the Chinese government that supports "on-the-move" communications.[21]



(JHU/APL Photo)

Figure 2. Tiantong SATCOM Terminals

ChinaSat-9A launched in June 2017 to provide "direct-to-home" broadcast and media services for the Chinese market. According to the ChinaSat website, this satellite has a "specially designed beam for the South China Sea area to guarantee the direct-to-home coverage of China's sovereign territory" (see Figure 3).[22] This SCS Ku-band Broadcast Satellite Service (BSS) with its ability to broadcast volumes of data, such as

[21] Hang Tianren and Liu Yang, " '中国版海事卫星' 有多强" [How Strong Is the "Chinese Maritime Satellite"], 环球时报 [Global Times], May 17, 2018, http://news.ifeng.com/a/20180517/58328745_0.shtml.

[22] "ChinaSat 9A," China Satellite Communications Co., Ltd., last modified July 21, 2017, http://english.csat.spacechina.com/n931903/c1694962/content.html.

video, still imagery and other large data files, to relatively small dish receivers in the SCS could have significant military utility.

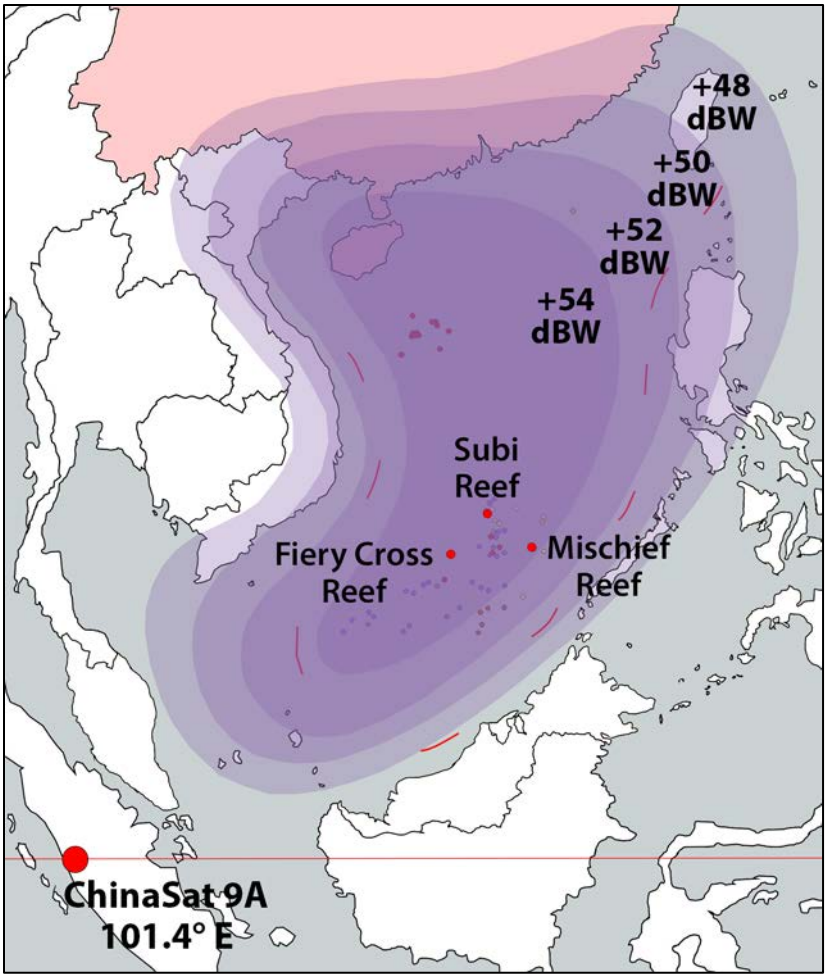
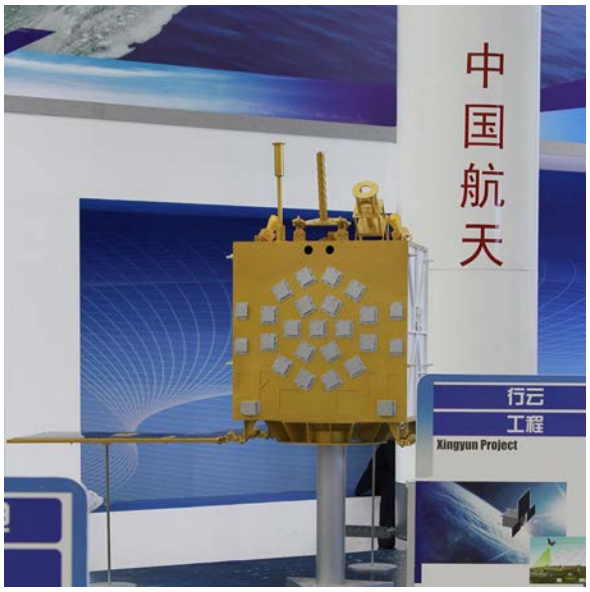


Figure 3. ChinaSat-9A BSS Footprint

Low-Earth-Orbit SATCOM

Chinese state-owned companies plan to deploy hundreds of small satellites in LEO to provide worldwide communications coverage for both civilian and military applications. These LEO satellite networks will increase capacity and offer additional redundancy for military SATCOM on the SCS outposts and surrounding waters. The state-owned China Aerospace Science and Industry Corporation (CASIC) and China Aerospace Science and Technology Corporation (CASC) are both developing LEO communications constellations. The Chinese military has historically enjoyed strong ties to the CASIC enterprise.

CASIC's 4th Academy, also known as the China Aerospace Sanjiang Group (中国航天三江集团有限公司) developed ballistic missile technology for the PLA. The 4th Academy leads CASIC's Xingyun (行云) or "Running Cloud" project. The Xingyun LEO constellation will consist of as many as eighty access and relay satellites utilizing narrow-band communications in L-band (1-2 GHz) (see Figure 4). The Xingyun satellites will provide next-generation Internet-of-things (IoT) connectivity by the mid-2020s. The first two operational satellites in the Xingyun constellation launched in May 2020.[23] The Xingyun project will support cloud computing and big data initiatives that could support the PLA Navy or other Chinese military forces deployed to remote locations such as the SCS.



(JHU/APL Photo)

Figure 4. Xingyun Satellite Model

CASIC's 2nd Academy, which has historically developed surface-to-air missiles, submarine-launched ballistic missiles, and other solid propellant missiles for the PLA, leads CASIC's Hongyun (虹云) or "Rainbow Cloud" project. The Hongyun LEO constellation is designed around one-hundred-fifty-six planned Ka-band (27–40 GHz) communications satellites that will provide global coverage for a mobile

[23] "行云工程" [Xingyun Project], CASIC (CASICloud), Accessed July 1, 2020, http://core.casicloud.com/zone/zoneCommercial/zoneCommercial/emphasisProject.ht?project=xy.

broadband Internet service. The first Hongyun satellite launched in December 2018. CASIC announced that the satellite will begin demonstrating capabilities in 2020.[24]

The CASC subsidiary "The East is Red" Low-Earth Orbit Satellite Mobile Communications Company (东方红低轨卫星移动通信公司) is developing the Hongyan (鸿雁), or "Wild Goose," LEO constellation to integrate with terrestrial cellular telecommunication networks. The first Hongyan satellite, launched in December 2018, is conducting L- and Ka-band communications tests through 2020. The first sixty Hongyan satellites are expected to be in operation by 2022. A plan for a larger Hongyan LEO satellite constellation of more than three hundred satellites will provide global coverage by 2025. CASC indicated that the Hongyan constellation will connect directly to China's anticipated build-out of the next-generation standard for wireless communications, a fifth-generation (5G) mobile network. Satellites networking to new 5G base stations and towers could reduce the deployment cost of China's 5G backhaul network. Leveraging the Hongyan SATCOM constellation could lead to a more rapid deployment of Chinese 5G networks, especially in remote areas like the SCS.[25]

A Chinese commercial startup, GalaxySpace (银河航天), is developing satellites for global 5G service from LEO. While GalaxySpace is a private Chinese venture, it enjoys significant support from state-owned companies, namely CASC and the China Electronics Technology Group Corporation (CETC). The Yinhe-1 (Galaxy-1) satellite launched in January 2020 and is expected to be the first of one hundred forty-four LEO satellites launched through 2023. Yinhe-1 will test Q/V and Ka-band communications at data speeds up to 10 Gbps.[26] The Yinhe constellation's objective is to provide high-bandwidth connectivity to remote areas and has great potential to support future PLA or civil-military operations in the SCS.

Beidou (北斗) Satellite Navigation Network

Military or civil–military operations in the SCS may be coordinated through China's Beidou (北斗) satellite navigation system. Unlike other Western or Russian satellite

[24] "虹云工程" [Hongyun Project], CASIC (CASICloud), Accessed July 1, 2020, http://core.casicloud.com/zone/zoneCommercial/zoneCommercial/emphasisProject.ht?project=hy.

[25] Chen Li and Dai Zhenying, "航天科技集团鸿雁星座研制进展与未来应用展望" [Development and Future Applications of the China Aerospace Science and Technology Group Hongyan Constellation], 中国航天报 [China Aerospace News], November 9, 2018, http://www.spacechina.com/n25/n2018089/n2018151/c2019057/content.html.

[26] Andrew Jones, "China Launches Yinhe-1 Commercial Low Earth Orbit 5G Satellite," *Space News*, January 16, 2020, https://spacenews.com/china-launches-yinhe-1-commercial-low-earth-orbit-5g-satellite/.

navigation systems, such as the US Global Positioning System (GPS), Beidou offers an imbedded S-band, two-way short-message service (SMS) that may be especially useful in an expansive maritime environment like the SCS. Chinese shipping and fishing fleets reportedly use Beidou SMS texting extensively. Chinese military newspaper articles noted the importance of the text messaging service in monitoring activities at sea and coordinating with civilian ship formations such as those from China's paramilitary maritime militia.[27] For additional information on Beidou positioning, navigation, and timing (PNT) capabilities, see the SCS MILCAP study, "Hardened Infrastructure, Battlespace Environmental Management, and Counter-Reconnaissance."

Chinese military SATCOM demonstrates a frequency diversity similar to other PLA communications and information-related capabilities. Figure 5 depicts the relative frequencies used by the different communications satellites outlined in this study. SATCOM systems such as the Fenghuo and Shentong-series satellites are certainly in use in the SCS in 2020. Newer systems, like the Shijian-series or the Xingyun and Hongyun LEO satellites, may be available for use by the mid-2020s. This graphic does not depict specific frequencies nor does it account for other Chinese government-commercial satellites operating in C-, Ka- and Ku-bands that probably augment dedicated PLA SATCOM.

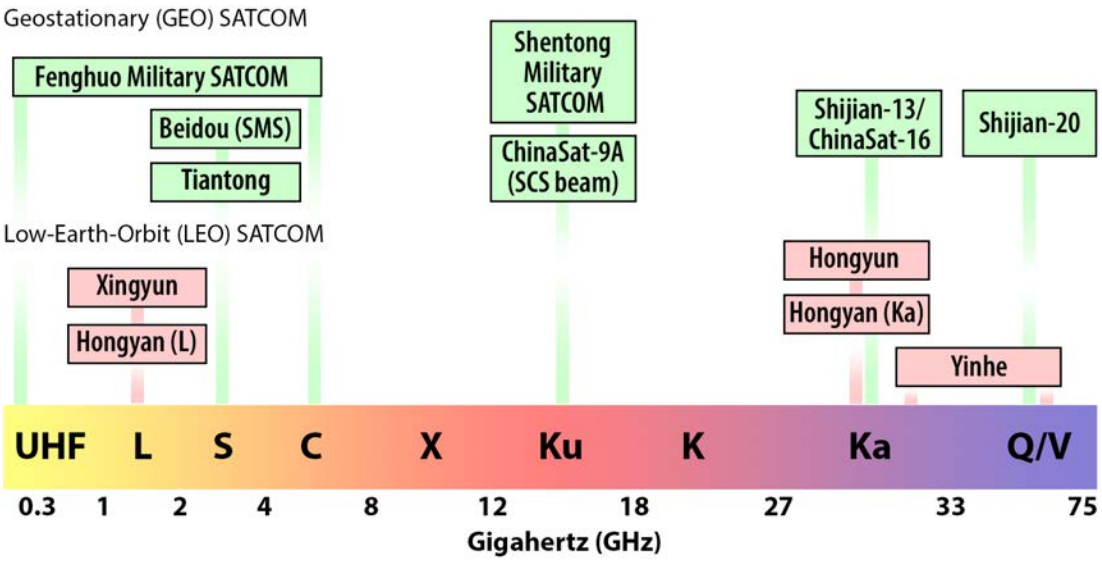


Figure 5. Relative Frequencies of Select Chinese SATCOM Systems

[27] Guo Bin and Lin Youwei, "有了北斗, 船艇多了双眼睛" [With Beidou, Boats Have More Eyes], 中国军网 [China Military Network], April 11, 2017, http://www.81.cn/gfbmap/content/2017-04/11/content_174603.htm.

SATCOM Infrastructure on SCS Island-Reefs

A review of high-resolution commercial satellite imagery reveals a large number of SATCOM dish antennae and environmental covers (radomes) that likely house larger SATCOM dishes. An examination of SATCOM on the SCS outposts is limited to the terrestrial infrastructure used to communicate with geostationary satellites (see Figure 6). Relatively small UHF antennae or sub-2-meter dishes are difficult to identify because of the limited resolution of commercial satellite imagery.

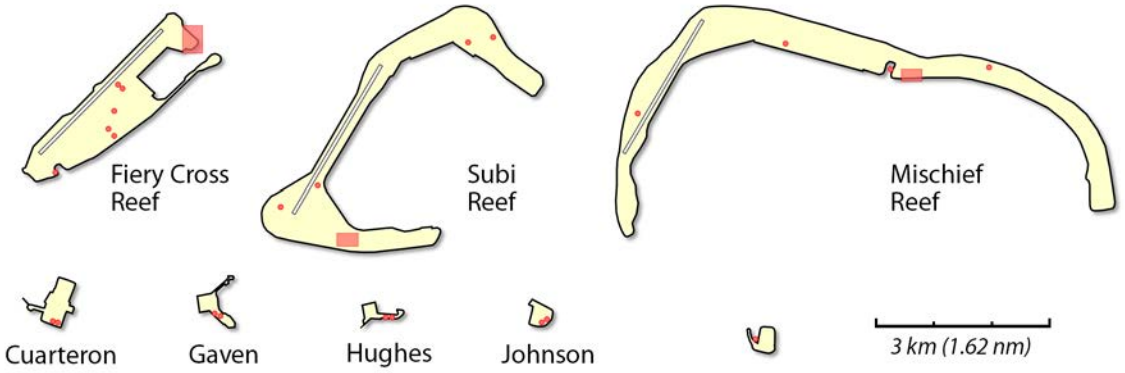


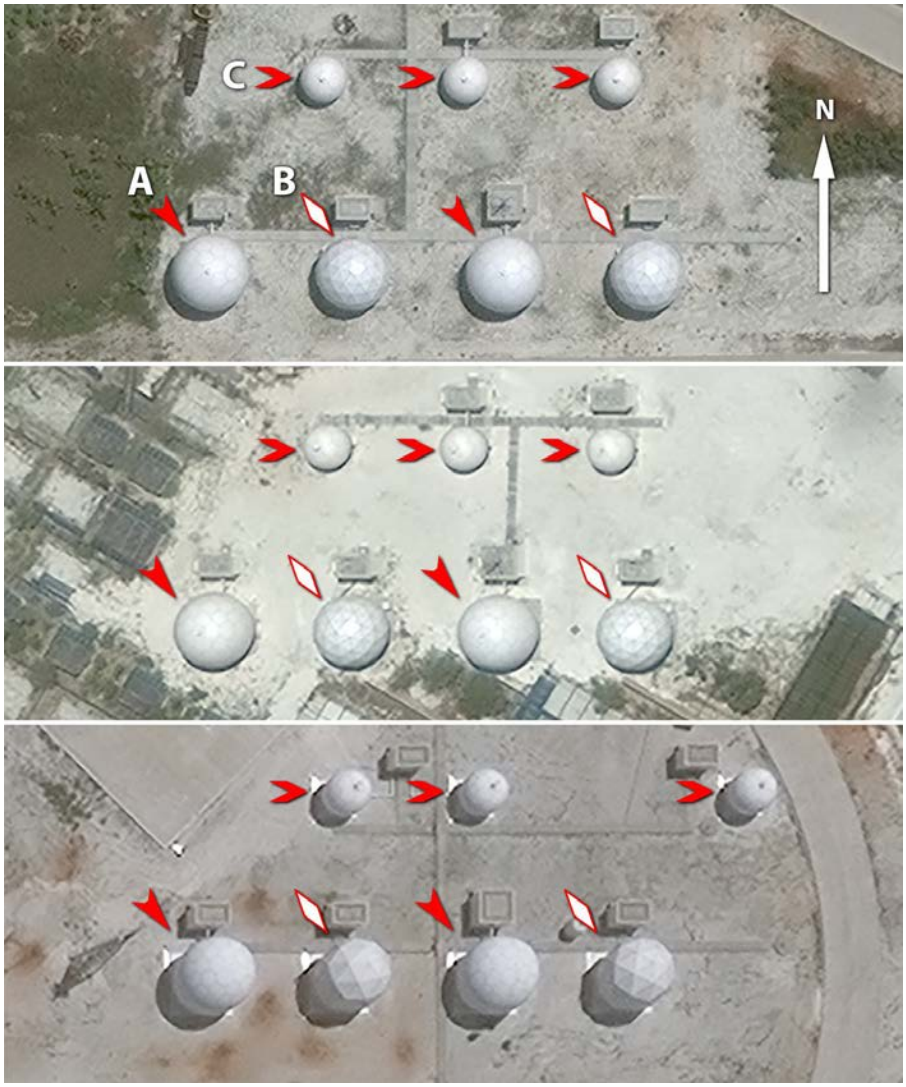
Figure 6. Observed SCS SATCOM Dish Locations, June 2018

Dish antennae housed in over thirty radomes across the SCS outposts are probably linked to both military and civilian geostationary telecommunication satellites. These dish housings not only serve to protect sensitive antenna electronics from the harsh marine environment. The radomes also act as a type of camouflage to deny an adversary the ability to observe antenna orientation that might determine where on the geostationary belt and toward which satellite a dish may be pointing. The large number of dish antennae and radomes underscores China's desire for significant communications redundancy in advancing its strategy to maintain information advantage in a military conflict.

High-Data-Rate SATCOM Gateways

Sets of large dish antennae provide access to SATCOM that are then probably networked via other shorter range communications throughout the island-reefs. Each major island-reef—Fiery Cross, Subi, and Mischief Reefs—have near-identical seven-radome sets consisting of two 12-meter (39-foot), two 11-meter (36-foot), and three 7-meter (23-foot) radomes. All the radomes are oriented east–west, and each likely houses a SATCOM dish antenna several meters smaller than the radome diameter. Generally, larger dish antennae are required for high-date-rate reception and transmission at lower frequencies (e.g., C-band), while smaller dishes may be used

for higher frequencies (e.g., Ku- or Ka-bands). Based on their presence on each island-reef, these seven-radome sets are likely SATCOM gateways providing high-capacity communications with military or civilian geostationary satellites (see Figure 7). (Note the three identical radome sizes: A, 12 meters; B, 11 meters; and C, 7 meters.)



(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 7. Common Seven-Radome SATCOM Set on Mischief Reef (Top), Subi Reef (Middle), and Fiery Cross Reef (Bottom)

The minor Chinese-held island-reefs are also part of an integrated SCS SATCOM network. Publicly available satellite imagery of Gaven, Hughes, Johnson, and Cuarteron Reefs indicates that each have a two-radome set consisting of one 12-meter (A-type) and one 11-meter (B-type) radome that appear to be identical to those on

the major island-reefs. The smaller outposts' SATCOM infrastructure likely reflects their smaller data throughput requirements. Leveraging the fiber-optic cable network and other means of inter-island communication, the smaller island-reefs may also have the ability to help "heal" the broader SCS island-reef network should major outpost communications suffer significant damage.

Additional Radomes at Fiery Cross Reef

Twelve additional radomes are adjacent to the common seven-radome SATCOM set on Fiery Cross Reef (see Figure 8). One 12-meter radome is located to the north on top of a probable communications building. The four 12-meter (39-foot) radomes just to the south of the seven-radome set may be additional B-type radomes. The remaining seven small radomes, consisting of four 9-meter (29-foot) and three 4-meter (13-foot) environmental coverings, do not appear on any other island-reef.

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 8. Twelve Additional Radomes on Fiery Cross Reef

The large number of radomes, and their colocation with the probable seven-radome SATCOM gateway, raises a number of possibilities. Some or all of the additional radomes may simply indicate a requirement for more SATCOM capacity on Fiery Cross Reef. Fiery Cross appears to be the principal command and control hub among the SCS outposts. Prior to 2014, it was the largest Chinese SCS outpost and was reportedly the first island-reef connected to the mainland by fiber-optic cable.

Based on the variation in sizes and slightly different design of the eleven-radome set compared to the seven-radome set seen on the other island-reefs, these radomes may also house dish antennae used for surveillance and reconnaissance of foreign satellites or, potentially, an electronic attack (i.e., jamming) capability against foreign SATCOM. For additional information on electronic warfare capabilities, see the SCS MILCAP study, "Electronic Warfare and Signals Intelligence."

Very-Small-Aperture Terminals

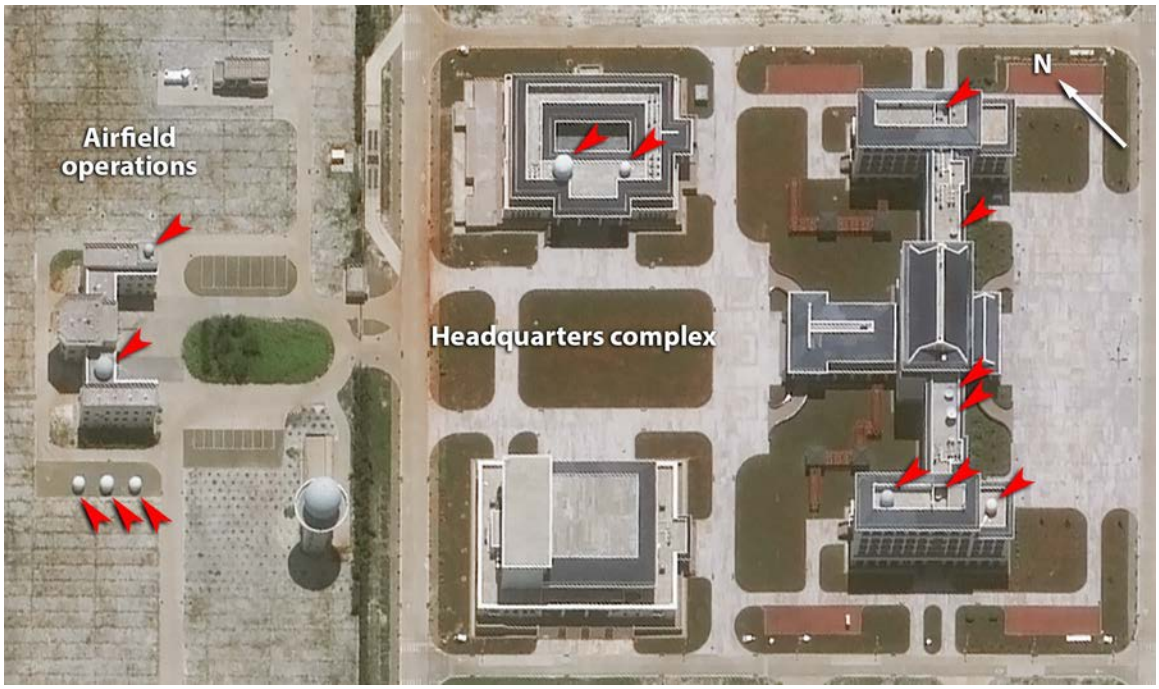
In addition to the high-data-rate SATCOM gateways, commercial satellite imagery reveals more than fifty very-small-aperture terminal (VSAT) dishes and radomes on the major SCS outposts. The observed VSAT dishes, generally smaller than 4 meters, probably support their colocated outpost facilities. SATCOM infrastructure detect-able on or near facilities includes dishes as small as 2 meters (6.5 feet) and radomes as large as 4 meters (13 feet). Additionally, most of the satellite dishes have not been removed from the original outpost structures subsumed by land reclamation and the expansion of the island-reefs (Figure 9). An accounting of fifty-seven observed VSAT dishes on major island-reefs is shown in Table 1. VSAT dishes smaller than 2 meters and similarly small helical UHF antennae could not be identified due to available commercial imagery resolution. An example of the large number of VSAT dishes and radomes visible at the Fiery Cross Reef airfield operations building and headquarters complex appear in Figure 10.

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 9. Original Fiery Cross Outpost

Table 1. Facility-Related Small SATCOM Dishes (VSAT) and Radomes Observed on Major SCS Island-Reefs, June 2018

Facility	Fiery Cross	Subi	Mischief
Old outpost structure	9	5	3
Headquarters complex	9	5	8
Airfield operations	5	3	5
Weather station	1	1	1
Hospital	1	–	–
Large unidentified building	1	–	–
Total new	**17**	**9**	**14**
Overall SATCOM total	**26**	**14**	**17**



(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 10. Fourteen Small Aperture SATCOM Radomes and Dishes at Fiery Cross Reef Headquarters and Airfield Operations

Conclusions

PLA forces on China's SCS island-reefs are likely connected by an undersea fiber-optic cable network that provides secure, reliable connectivity with headquarters and other military forces in the Paracels and on the Chinese mainland. Island-reef SATCOM capabilities, like other communications or reconnaissance capabilities on China's SCS island-reefs, appear to be diverse and redundant. The Chinese military has a range of SATCOM capabilities available that operate across the frequency spectrum. These SATCOM services are likely accessed through more than three dozen large SATCOM dishes housed in radomes across the seven island-reefs. These SATCOM capabilities are further augmented by scores of smaller aperture dishes collocated with different outpost facilities. Even smaller, sub-2-meter dishes and SATCOM antennae are almost certainly present on the SCS outposts but are difficult to detect in commercial imagery. New Chinese SATCOM systems providing communications with handsets and mobile, "on-the-move" antennae are virtually impossible to detect even with the highest resolution imagery. In the near future, emerging 5G cellular and IoT services may be linked from small, circuit board-sized transceivers through cellular base stations up to 5G LEO satellites. These technologies have significant potential to improve military communications given 5G improvements in data speed and volume.

Undersea fiber-optic cable and SATCOM will be integrated with other Chinese SCS outpost communications capabilities. The strength of the PLA's communications network is not found in any one system but in the diversity, redundancy, and resilience of the PLA's communications system-of-systems. Undersea fiber-optic cable, SATCOM, and HF communications are integrated with shorter range, inter-island systems such as troposcatter communications, 4G cellular service, and very high frequency (VHF)/UHF-band line-of-sight communications. The redundancy and structure of the PLA's SCS communications offer dozens of different combinations to support a self-healing network. In a conflict, as different communications are jammed or physically damaged, battlespace information as well as command and control may be rerouted from one link to the next through ships, aircraft, and the island-reefs until communications reach their intended destination (see Figure 11).

PLA investment in undersea fiber-optic cable and SATCOM demonstrates an informationized warfare strategy that emphasizes information control in both peacetime and conflict. Robust and redundant communications utilize different pathways and cover a broad swath of the electromagnetic spectrum. Countering the PLA's ability to communicate in a conflict will involve simultaneously interfering with or destroying a number of Chinese communication means to deny PLA designs to gain and maintain battlespace information advantage.

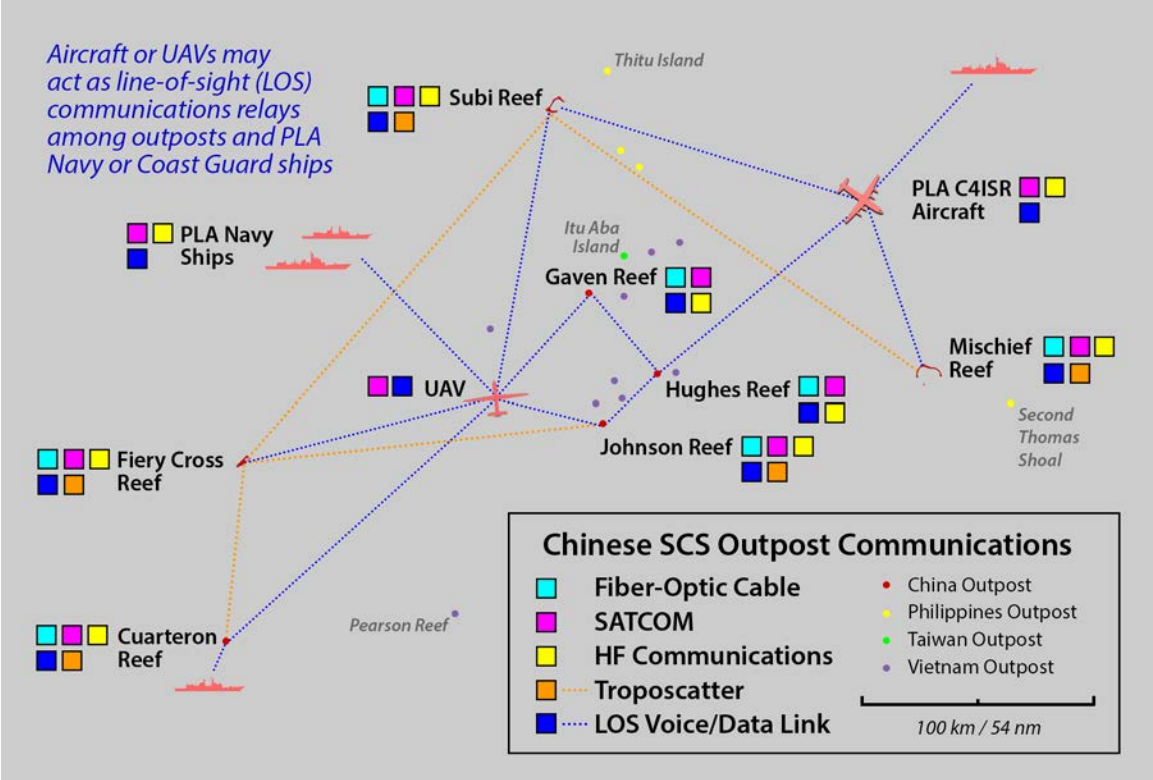


Figure 11. Chinese SCS Outpost Communications

Appendix A. Sources and Methods

Observations and analysis of the Chinese SCS outposts in these MILCAP studies rely on commercial satellite imagery licensed to JHU/APL and collected by the Maxar/DigitalGlobe Inc. WorldView-3 satellite (see Table 2). WorldView-3 can collect images up to 30-centimeters resolution, which translates to image quality between 5.0 and 6.0 on the National Imagery Interpretation Rating Scale (NIIRS).[28] For these studies, software like Google Earth Pro and Adobe Photoshop were used to interpret imagery, measure features, and adjust image color and balance. These images were not subject to any special processing or proprietary enhancements.

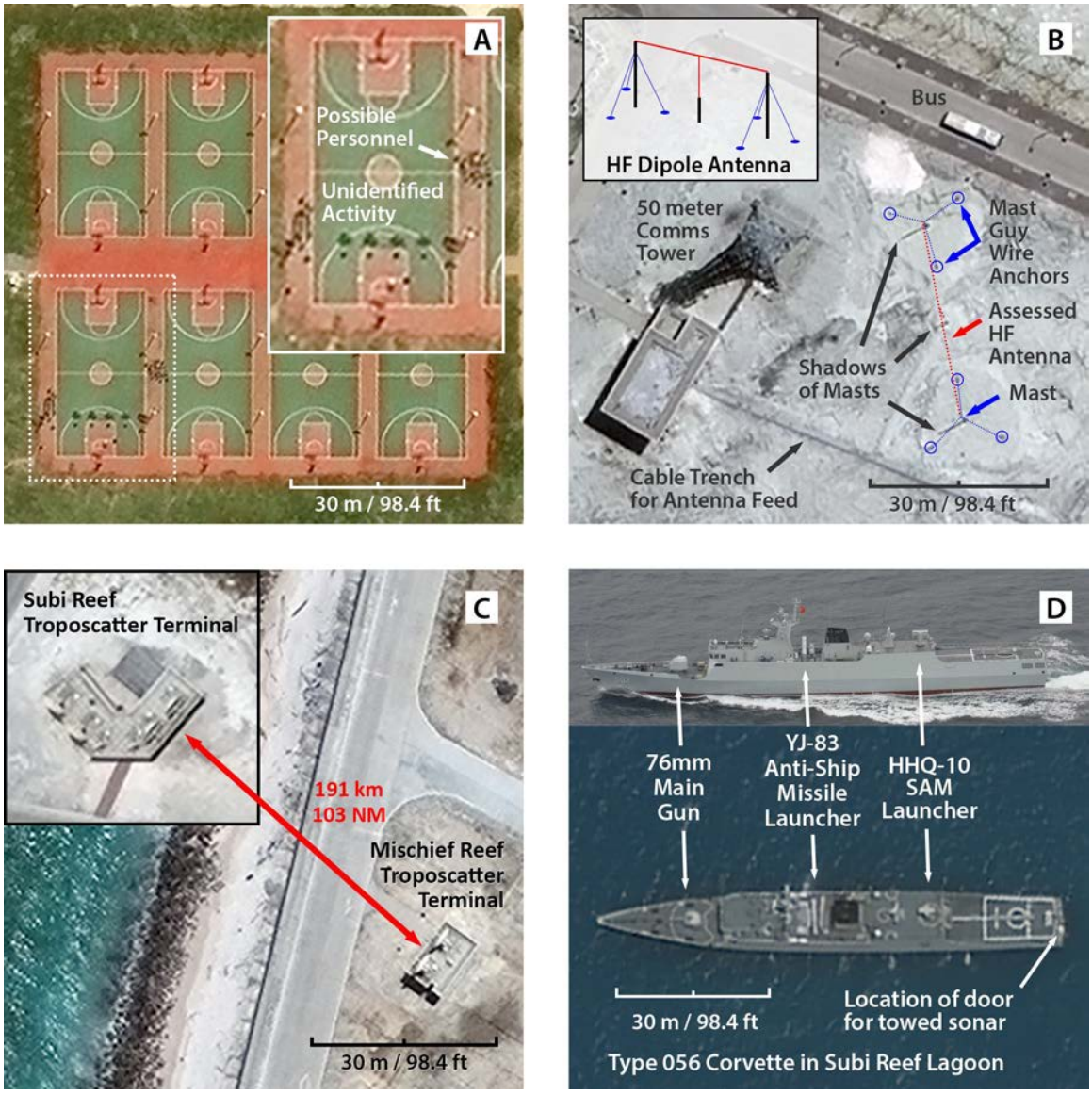
Table 2. DigitalGlobe Inc. WorldView-3 Satellite Imagery Details

Island-Reef	Location	Date	DigitalGlobe Image ID
Fiery Cross Reef	09°33′00″ N, 112°53′25″ E	June 14, 2018	104001003C49BB00
Subi Reef	10°55′22″ N, 114°05′04″ E	June 19, 2018	104001003E841300
Mischief Reef	09°54′10″ N, 115°32′13″ E	June 19, 2018	104001003D964F00

Reference images published in these studies cover hundreds of square meters, which necessarily obscures many specific features used in making assessments. Zoomed-in examples of details available in these satellite images are shown in Figure 12. The dots made up of only a few pixels in Figure 12(A) cannot be readily identified. However, their location on the basketball court leads to a conclusion that these may be personnel. As shown in Figure 12(B), observing shadows and other features may reveal structures such as a common HF dipole antennae, even if the fine-gauge wires cannot be seen in the image. Shadow length may be translated into object height using satellite image metadata and simple trigonometry. Figure 12(C) is an example that indicates the likely connection between two widely separated troposcatter terminals based on antenna pointing angles. Figure 12(D) demonstrates that positive identification of detailed features may be possible with a much higher quality reference image. The PLA Navy Type 056 corvette in the satellite image may be an anti-submarine warfare variant (Type 056A) based on the light colored feature seen where the door for a towed sonar array should be located.[29]

[28] Leigh Harrington, David Blanchard, James Salacain, Stephen Smith, and Philip Amanik, *General Image Quality Equation; GIQE version 5*, (Washington, DC: National Geospatial-Intelligence Agency (NGA), 2015), https://gwg.nga.mil/ntb/baseline/docs/GIQE-5_for_Public_Release.pdf.

[29] See close-up images of the towed array door in "'Sanmenxia,' First Type 056A ASW Corvette (Jiangdao Class), Commissioned in Chinese Navy (PLAN)," *Navy Recognition*, November 19, 2014, accessed July 1, 2020, http://navyrecognition.com/index.php?option=com_content&view= article&id=2189.



(Images © 2020 Maxar/DigitalGlobe, Inc. Photograph of ship courtesy of Japan Self Defense Force)

Figure 12. Detailed Image Examples. (A) Mischief Reef Basketball Courts, (B) Mischief Reef HF Antenna, (C) Troposcatter Terminals, (D) Type 056 Frigate

Publicly accessible satellite imagery, available on Google Earth or from organizations like the Asia Maritime Transparency Initiative, provides historical images that may show changes to island-reef features over time. Official or semi-official Chinese sources discussing military capabilities on the SCS outposts complement imagery analysis and help qualify imagery observations. Where appropriate, these studies also reference secondary sources such as credible media reporting on China's SCS island-reefs or public U.S. government statements about PLA capabilities in the SCS.

Appendix B. South China Sea Maritime Territorial Claims

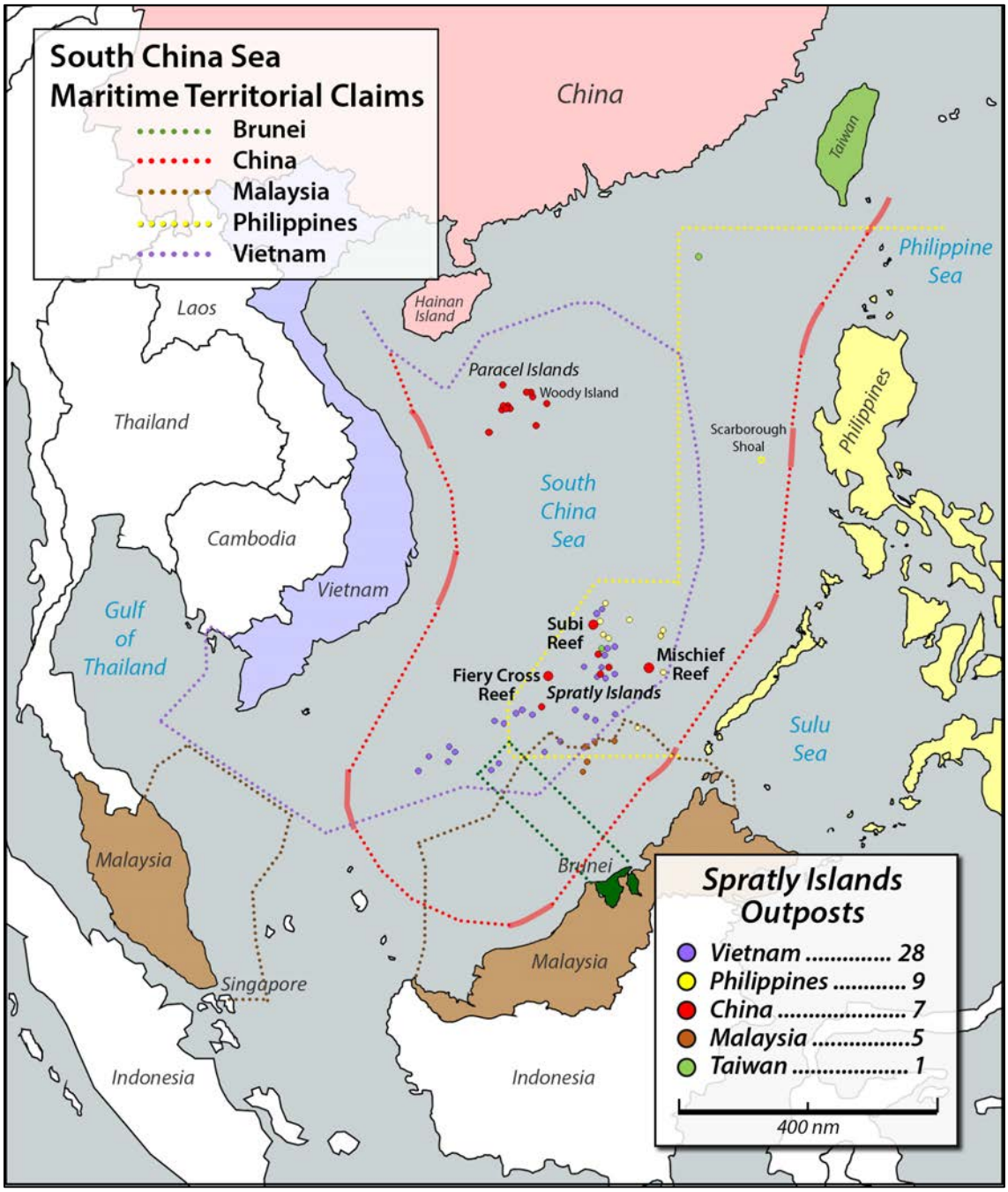


Figure 13. South China Sea Maritime Territorial Claims

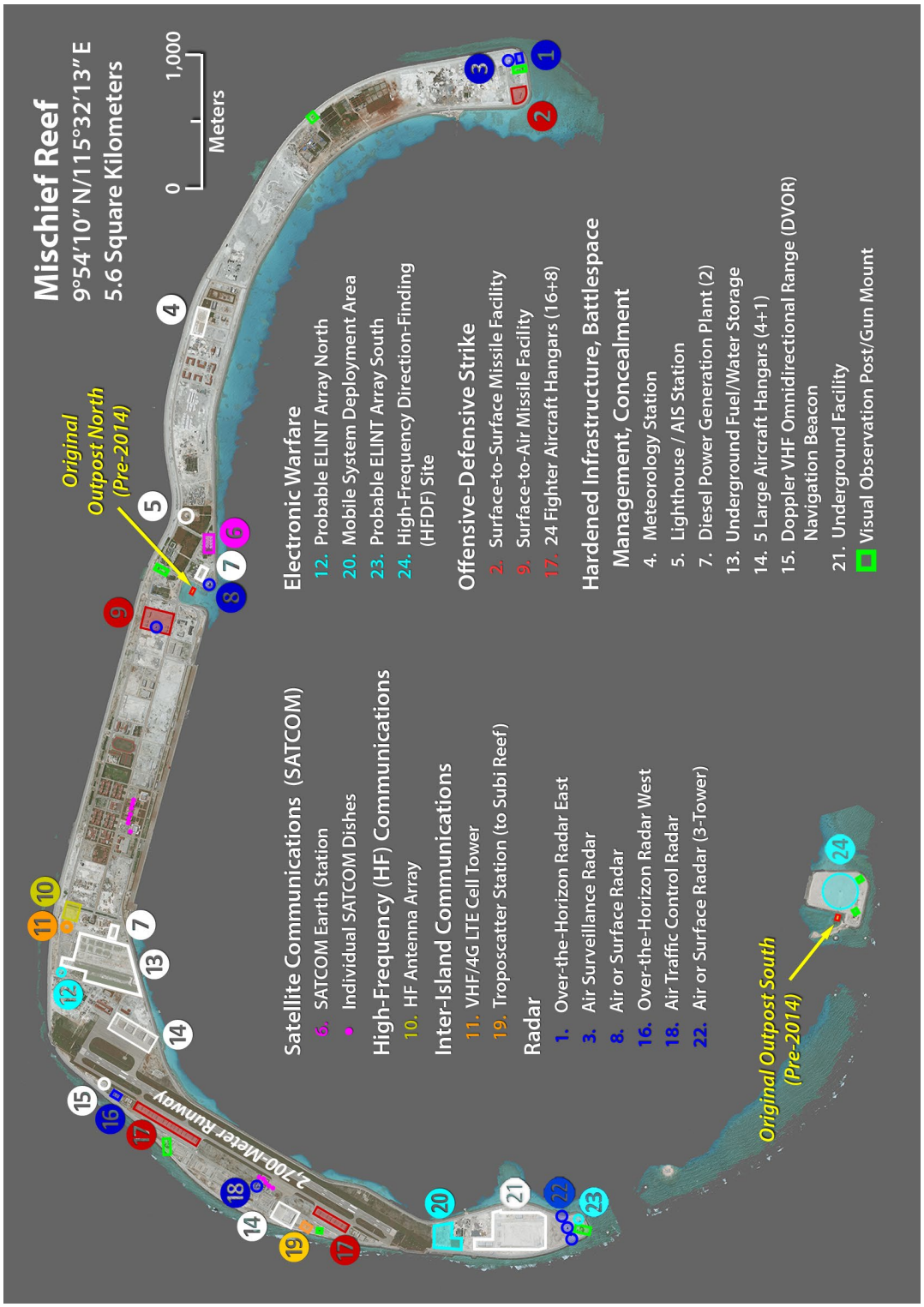
Appendix C. Island-Reef Capabilities Overview Graphics

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 14. Fiery Cross Reef Overview

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 15. Subi Reef Overview



(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 16. Mischief Reef Overview

Appendix D. Definitions and Abbreviations

AIS—Automatic identification system; tracking system used by large ships

4G LTE—Fourth-generation long-term evolution; cellular communications

ASCM—Anti-ship cruise missile

C4—Command, control, communications, and computers. Sometimes rendered C3, dropping "computers" or C2, "command and control"

C4ISR—Command, control, communications, computers, intelligence, surveillance, and reconnaissance. Sometimes C5ISR or C5ISRT, including "cyber" and "targeting"

CCD—Camouflage, concealment, and deception

ELINT—Electronic intelligence

EMS—Electromagnetic spectrum; common frequency bands are shown in Table 3

Table 3. Radio and Radar Frequency Bands

ITU Radio Bands	Band Name	Frequency Range	IEEE Radar Bands	Frequency Range
VLF	Very-low frequency	3-30 kHz		
LF	Low frequency	30-300 kHz		
MF	Medium frequency	300-3000 kHz		
HF	High frequency	3-30 MHz		
VHF	Very-high frequency	30-300 MHz	VHF	30-300 MHz
UHF	Ultra-high frequency	300-3000 MHz	UHF	300-1000 MHz
			L	1-2 GHz
SHF	Super-high frequency	3-30 GHz	S	2-4 GHz
			C	4-8 GHz
			X	8-12 GHz
			Ku	12-18 GHz
			K	18-27 GHz
			Ka	27-40 GHz
EHF	Extremely-high frequency	30-300 GHz		

EW—Electronic warfare

HFDF—High-frequency direction finding

Information power—信息力 (*xìnxī lì*)—A Chinese term referring to the capability of a military force to achieve information superiority, ensuring the use of information for friendly operational forces while simultaneously denying adversary operational forces the use of information

Informationized warfare—信息化作战 (*xìnxī huà zuòzhàn*)—The prevailing "form of war" (战争形态, *zhànzhēng xíngtài*) in Chinese military theory.

Island-reef—岛礁 (*dǎo jiāo*)—A Chinese term for an islet or an island of sand that has built up on a reef. China's military outposts in the Spratly Island group were formerly rocks or high-tide features that do not have the international legal status of island that might otherwise define territorial waters or an exclusive economic zone

ISR—Intelligence, surveillance, and reconnaissance

PLA—People's Liberation Army; Refers to the entire Chinese military

PLAN—People's Liberation Army Navy

PNT—Positioning, navigation, and timing

SATCOM—Satellite communications

SAM—Surface-to-air missile

SCS—South China Sea

SoS—System-of-systems.

Southern Theater—One of five PLA theater commands created in 2016 Chinese military reorganization. Area of responsibility includes southern China, Hainan Island, the SCS, and Paracel and Spratly island-reef bases

SSF—PLA Strategic Support Force

SSM—Surface-to-surface missile

Troposcatter— Troposcatter or tropospheric communications are microwave signals, generally above five hundred megahertz, scattered by dust and water vapor in the atmosphere, allowing for over-the-horizon communication links

UAV—Unmanned aerial vehicle

USV—Unmanned surface vehicle

UUV—Unmanned underwater vehicle

About the Author

J. Michael Dahm is a senior national security researcher at the Johns Hopkins University Applied Physics Laboratory where he focuses on foreign military capabilities, operational concepts, and technologies. Before joining JHU/APL, he served as a US naval intelligence officer for over 25 years. His most recent assignments included senior analyst in the USPACOM China Strategic Focus Group, assistant naval attaché at the US embassy in Beijing, China, and senior naval intelligence officer for China at the Office of Naval Intelligence.

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