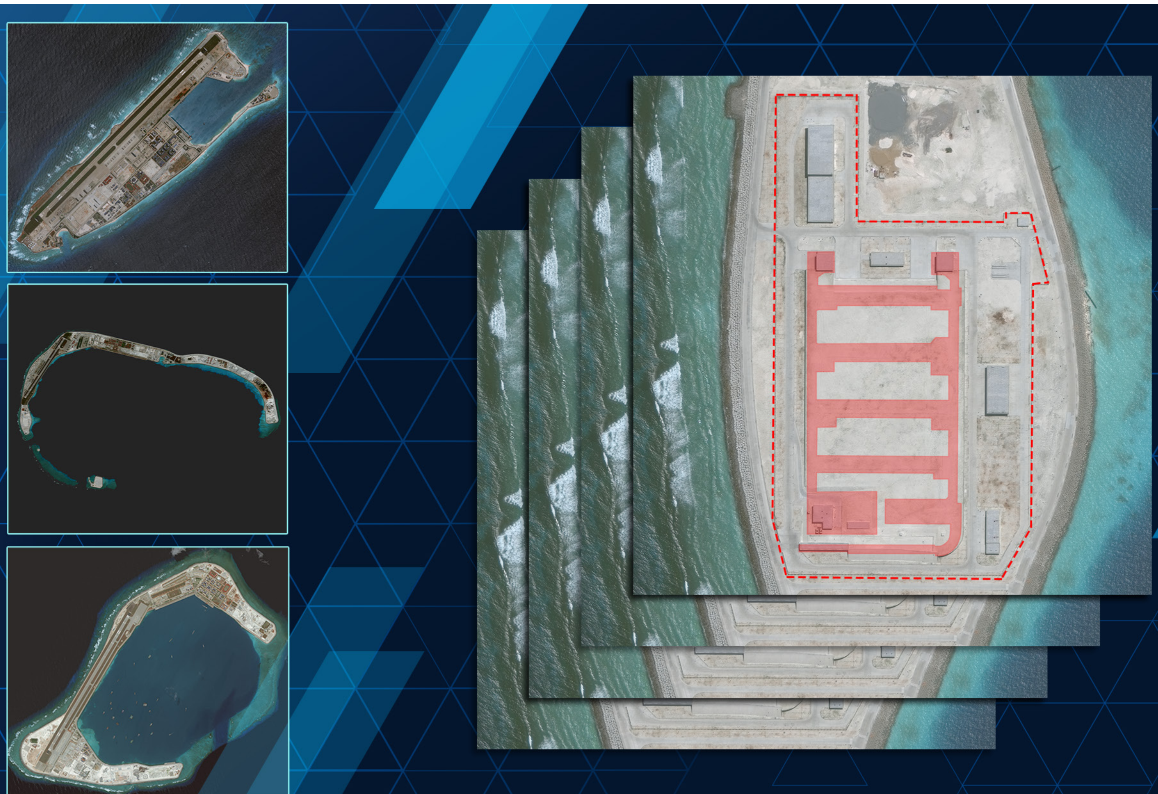
SOUTH CHINA SEA MILITARY CAPABILITY SERIES

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



HARDENED INFRASTRUCTURE, COUNTER-RECONNAISSANCE, AND BATTLESPACE ENVIRONMENT MANAGEMENT

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Introduction

This military capability (MILCAP) study focuses on hardened infrastructure, counter-reconnaissance, and battlespace environment management capabilities on seven Chinese island-reef outposts in the South China Sea (SCS). 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.

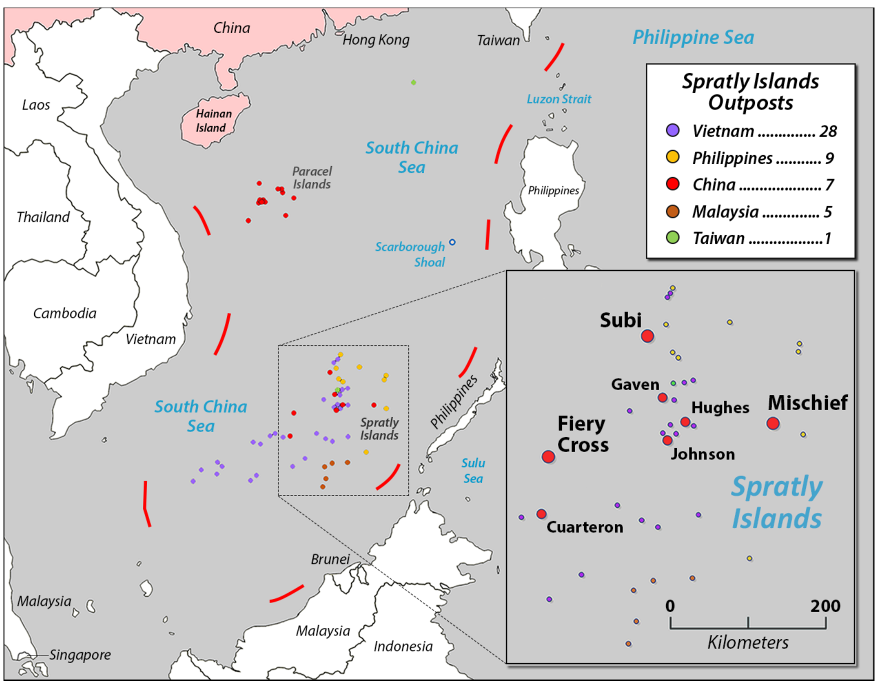

Figure 1. SCS Occupied Features

The PLA made significant investments in hardened infrastructure and counter-reconnaissance to conceal and protect critical military capabilities in the SCS. Concealment, camouflage, and deception measures are key elements of integrated Chinese military system of systems designed to gain and maintain information superiority in any SCS conflict. Efforts to manipulate the physical information space are complemented by PLA efforts to exploit the battlespace environment by collecting detailed data on weather and hydrological conditions from their SCS outposts. This information may be a critical enabler for sonar or electromagnetic systems. Overview graphics of all capabilities noted on major outposts appear in Appendix C.

Hardened Infrastructure

Physical hardening is necessary to protect island-reef infrastructure against the harsh marine environment and natural disasters such as typhoons or to protect facilities from attack. The primary purpose of hardened infrastructure is to decrease vulnerabilities. However, hardening may also serve to enhance the PLA's information power capabilities, obscuring activity from view and denying an adversary information about Chinese intentions and the status of different island-reef systems.

Artificial Island Construction

While not directly related to information power, the physical characteristics of the Chinese artificial islands demonstrate the durability of the PLA island-reefs. These PLA outposts are described in some media accounts as China's "great wall of sand."[1] However, these Chinese bases should not be dismissed as glorified sand castles. China is the world leader in modern-day land reclamation projects and has ready access to the technology and expertise necessary to build durable artificial islands in the SCS. Since the 1940s, China reclaimed coastal land or built artificial islands along its coastline totaling over 14,000 square kilometers.[2]

Chinese studies of Spratly Island reef geology began in 1988 after PLA forces first occupied Fiery Cross Reef. Chinese five-year development plans in the early-1990s directed geological surveys and engineering assessments of Chinese-held SCS reefs.[3] Drilling and core sampling along the edges of the reefs revealed over 2,000 meters of solid reef limestone just below the surface of the water. In the center of the reef, filled with sand and coral debris, reef limestone began between 17 and 20 meters (55–66 feet) below the surface.[4] The limestone on the outer boundary of the reef provides a solid framework for roads, runways, and buildings built on the artificial islands. By 2008, research led by the Chinese Academy of Sciences indicated that massive coral limestone structures like Fiery Cross, Subi, and Mischief Reefs were suitable for large-

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[1] Alexander Neill, "South China Sea: What's China's Plan for its 'Great Wall of Sand'?" *BBC News*, July 14, 2020, https://www.bbc.com/news/world-asia-53344449.

[2] Hu Cong, You Zaijin, Mao Haiying, and Hu Xiaoming, "Assessing Impacts of Large-Scale Coastal Land Reclamation on Marine Environment on the Coast of China," *Journal of Coastal Research* 85 (1 May 2018): 1486.

[3] Zhao Huanting, Song Chaojing, Lu Bo, Wang Ren, and Yang Zhiqiang, "珊瑚礁工程地质初论" [A Preliminary Exposition of Coral Reef Engineering Geology], *工程地质学报 [Journal of Engineering Geology]* 4, no. 1 (March 1996): 88.

[4] Meng Qingshan, Yu Kefu, Wang Ren, Qin Yue, Wei Houzhen, and Wang Xinzhi, "Characteristics of Rocky Basin Structure of Yongshu Reef in the Southern South China Sea," *Marine Georesources and Geotechnology* 32, no. 4 (2014): 309-310.

scale engineering projects, including runways and airports.[5] Land reclamation and building activity on the seven Chinese-held Spratly island-reefs began in March 2014.

Sand in the SCS used in Chinese artificial island construction is calcareous sand composed primarily of ancient marine life. Calcareous sand is superior in terms of compressibility and compactability, compared to silica sand commonly found along the east and west coasts of the United States.[6] Calcareous sand and crushed coral rock were used to fill the interior of the artificial islands that are now encircled by a substantial reef limestone boundary topped with a concrete perimeter road. Large areas of the island-reefs are probably paved over with a cement stabilized macadam composed of a small amount of Portland concrete mixed with calcareous sand harvested from the reef interior.[7]

Waves are diminished as they break over the natural reef that extends 100–200 meters from the artificial islands. Concrete sea walls or concrete tetrahedral-shaped blocks (tetrapods) encircle the island-reefs and provide additional protection against wave action and erosion (see Figure 2). The artificial land that undergirds these PLA bases appears to be built to endure significant tropical storms or bombardment.

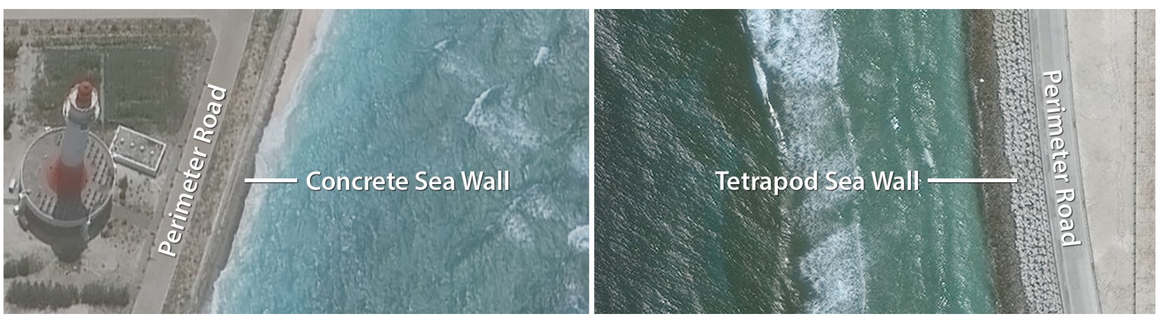


Figure 2. Sea Walls on Fiery Cross Reef (Left) and Mischief Reef (Right)

[5] For a comprehensive summary of Chinese reef engineering research as of 2008, see Wang Xinzhi, "南沙群岛珊瑚礁工程地质特性及大型工程建设可行性研究" [Study on Engineering Geological Properties of Coral Reefs and Feasibility of Large Construction on Nansha (Spratly) Islands] (PhD diss., Chinese Academy of Sciences, Wuhan, 2008), 109-111, CNKI

[6] Wang Xinzhi, Jiao Yuyong, Wang Ren, Hu Mingjian, Meng Qingshan, and Tan Fengyi, "Engineering Characteristics of Calcareous Sand in Nansha (Spratly) Islands, South China Sea," *Engineering Geology* 120 (2011), 40-47.

[7] The Chinese Communications Construction Corporation (CCCC) was responsible for much of the SCS island-reef land reclamation. In 2015, CCCC applied for a patent that likely provides insights to its artificial island construction process. See, CCCC, 1st Navigation Bureau, 4th Engineering Company, 水泥稳定珊瑚礁砂施工工艺 [Cement-Stabilized Coral Reef Sand Construction Process], Chinese Patent CN105369721A, filed November 10, 2015, https://patents.google.com/patent/CN105369721A/en.

Underground Facilities

Sets of underground facilities (UGFs) were constructed on each of the three major outposts. These UGFs probably warehouse ammunition, conceal weapons loading activity from view, and store vast amounts of fuel and water (see Figure 3). Commercial satellite images between 2016 and 2017 show the tunnel complexes and bunkers under construction indicating the layout of the now buried structures.[8]

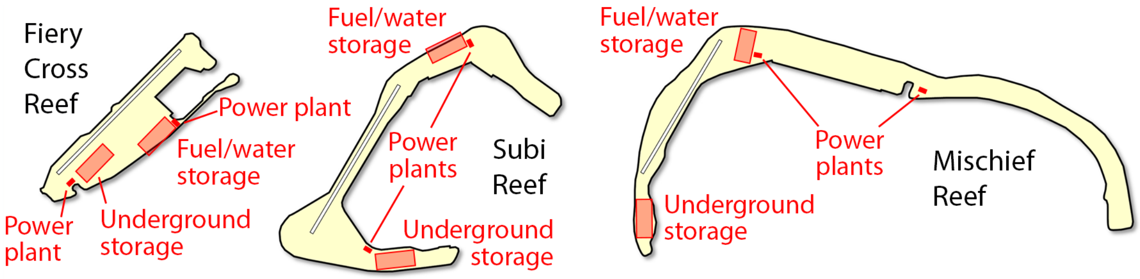


Figure 3. Locations of Underground Facilities and Power Plants

The major island-reefs have identical UGF bunker complexes. Probable ammunition storage UGFs consisting of five tunnels at or slightly below sea level are covered with sand and rock. The tunnels are probably separated to mitigate accidents or airstrikes and the potential for sympathetic detonation of any munitions stored inside. These UGFs provide in excess of 25,000 square meters (269,000 square feet) of protected space. A drive-in entrance accommodates large vehicles. Three buildings atop the tunnel complex may provide additional access to the bunkers using ramps or elevators. A high-bay hanger adjacent to each UGF probably allows for the maintenance and loading of missile launchers or other large weapon systems. Figure 4 numbers the identical buildings at each facility and outlines the buried structure.

Each major island-reef also has buried tanks that likely store fuel and water. Commercial satellite imagery from 2016 shows the tanks under construction.[9] The larger tanks shown in Figure 5 likely store fresh water. The smaller tanks, isolated from each other to increase survivability against attack and prevent cross-contamination from leaks probably hold fuel for vehicles, aircraft, ships, and island-reef diesel power plants. The depth of the tanks could not be determined from available imagery, but assuming a depth of 7 meters (23 feet), fuel storage on each

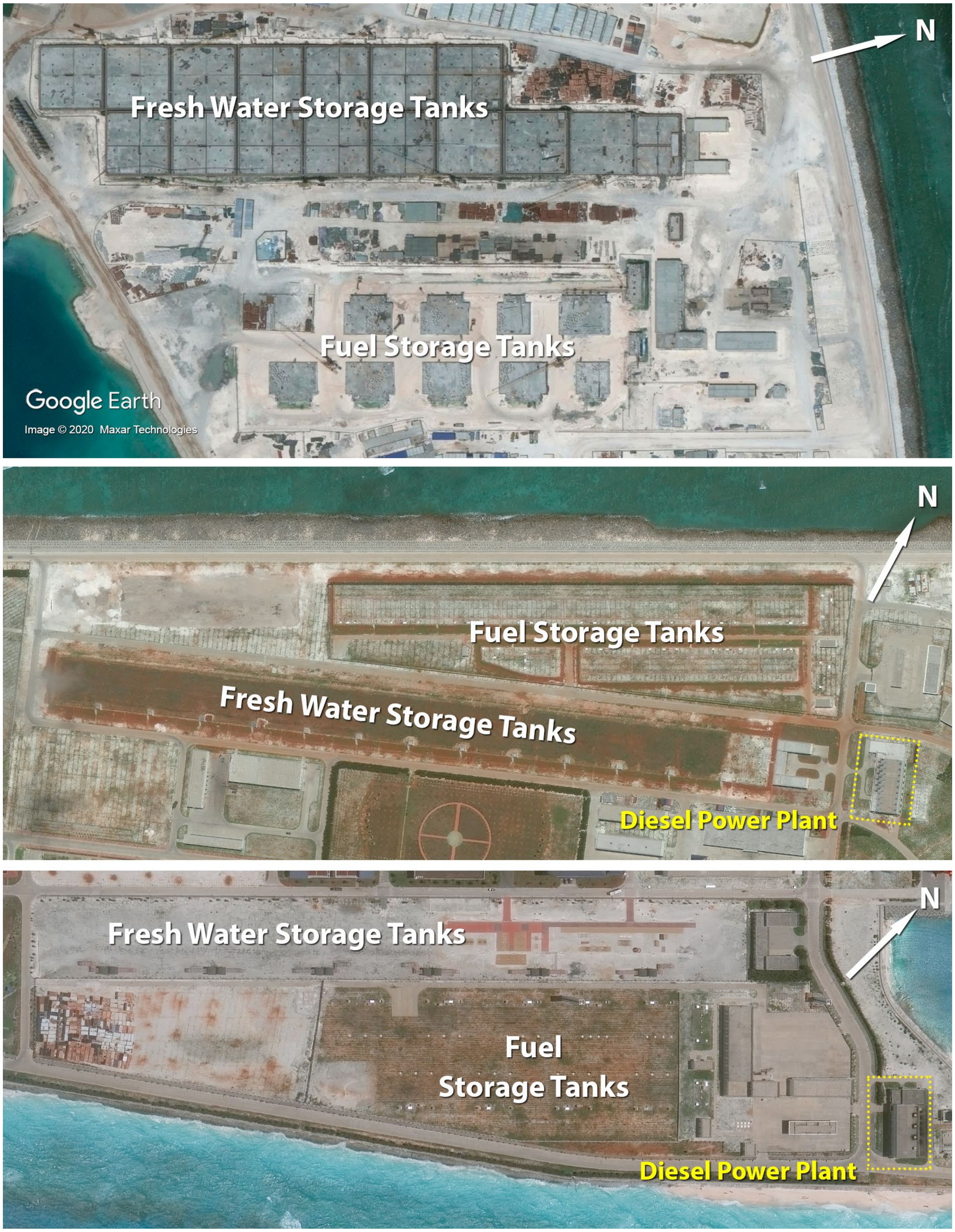
[8] "A Constructive Year for Chinese Base Building," Asia Maritime Transparency Initiative, December 14, 2017, https://amti.csis.org/constructive-year-chinese-building/.

[9] Google Earth Pro 7.3, DigitalGlobe Imagery dated April 30, 2016, 105624N/1140502E, 0 ft., and DigitalGlobe Imagery dated April 30, 2016, 095550N/1153105E, 0 ft., accessed March 29, 2019.

major island-reef may exceed 45 million liters (12 million gallons). Fuel and water storage can likely support several weeks of operations without resupply.

(Images © 2020 Maxar/DigitalGlobe, Inc.)

Figure 4. Underground Facilities and Support Buildings on Subi Reef (Top), Mischief Reef (Left), and Fiery Cross Reef (Right)



(Images © 2020 Maxar/DigitalGlobe, Inc.)

Figure 5. Storage Tanks Under Construction on Mischief Reef in 2016 (Top), Underground Storage Tanks on Subi Reef (Middle) and Fiery Cross Reef (Bottom)

Electrical Power Generation and Distribution

Diesel electric power plants appear to provide power for the island-reefs. Commercial satellite imagery shows two power plants on each major outpost. One plant is located adjacent to the underground fuel bunkers. The second plant is located several kilometers away, probably to mitigate the potential loss of both plants in an attack or other disaster. Apparent diesel exhaust scarring reveals that the Fiery Cross power plants operate six diesel generators each. Subi Reef plants also operate six diesel generators but apparently have space for an additional three generators. Mischief Reef diesel power plants may operate as many as eight generators, with space for an additional two (see Figure 6). Diesel generators that would fit in the power plant's 6 meter (20 foot) wide generator bays likely produce between 2 and 4 megawatts of electricity each.[10] Assuming a 2-megawatt output per generator, the two plants on Fiery Cross and Subi Reefs are capable of generating 24 megawatts of electrical power for each island-reef while the two Mischief Reef plants can generate 32 megawatts.

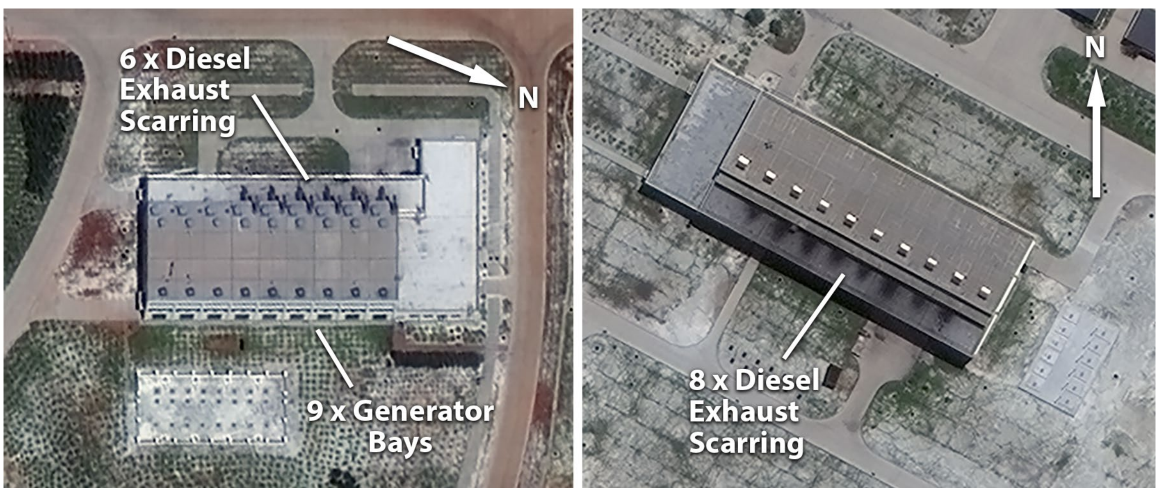


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Figure 6. Diesel Power Plants on Subi Reef (Left) and Mischief Reef (Right)

Electrical power is apparently distributed throughout the island-reefs by buried cables. Neither open-air transformer stations nor overhead power lines can be seen in commercial satellite imagery. There are hundreds of streetlights visible throughout the outposts, but overhead lines have not been observed in commercial satellite imagery, handheld photography, or video of the bases. Burying electrical wiring and

[10] Commercial 2-MW diesel powered electric generators average ~2.5 meters wide and requires ~3-4 meter spacing in a generator hall. Higher wattage generators with additional engine cylinders are longer, but not necessarily wider. See, for example, "High Voltage Generator Series," Guangdong Honny Power-Tech Co. Ltd., accessed September 9, 2020, http://www.honnypower.com/Power2/.

communications cables protects them from attack or natural disaster and prevents an assessment of the island-reef electrical and communications grid.

Solar panels and wind turbines have been noted on the smaller Johnson Reef outpost, but not on the major Chinese island-reefs. Eventually, all of the SCS outposts may incorporate solar and wind power in individual island-reef "microgrids" to increase efficiencies and extend on-island fuel supplies. Chinese media reported that Woody Island in the Paracel Islands achieved significant efficiencies with the advent of an intelligent microgrid regulated from the mainland. Commentators noted that the microgrid model will likely be exported to other SCS island-reefs.[11]

Counter-Reconnaissance

In January 2018, the *PLA Daily* newspaper ran a feature column for thirty-six consecutive weeks on China's "Thirty-Six Stratagems (三十六计)." These three dozen proverbs, taken from Chinese military history and folklore, underscore the role of cunning and deception in warfare. Far from being considered anachronistic, the column analyzed one ancient stratagem each week to demonstrate its relevance to modern military operations and inform the "preparation of future military struggles." To underscore its use of camouflage and deception in operations and exercises, the PLA often uses an important idiom born of the Thirty-Six Stratagems: "隐真示假," "hide what is real, show what is false."[12]

Camouflage, concealment, and deception (CCD) will be an integral part of PLA military operations in the SCS. As shown in the previous section, in many cases, hardened infrastructure directly lends itself to CCD that denies an adversary access to information about PLA activities and intentions. Preparations for military action may take place in underground facilities. In anticipation of an offensive, the PLA may also top-off fuel supplies. The concrete and sand covering the tanks may prevent intelligence, surveillance, and reconnaissance (ISR) sensors from indicating tank storage levels, denying an adversary indications and warning of PLA operations.

The PLA built CCD features into its artificial islands due to the relatively small area of the island-reefs and their lack of terrain or vegetation. The outposts are replete with

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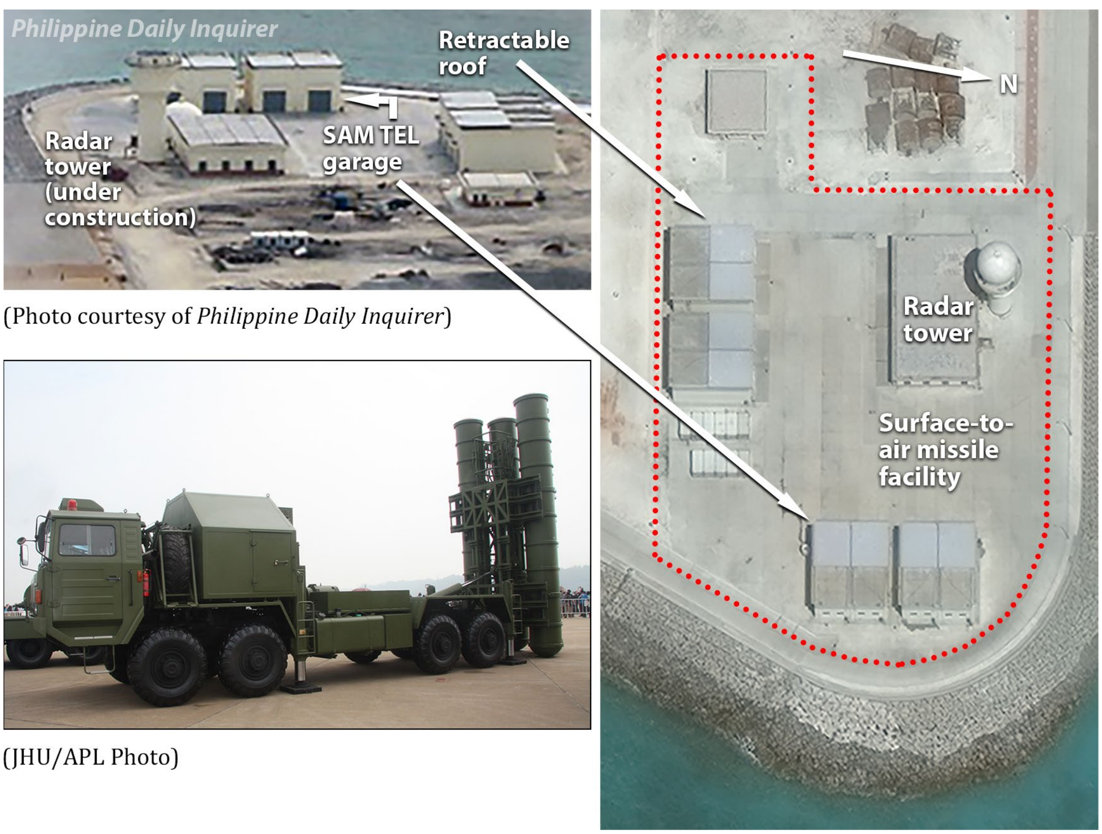
[11] Liu Caiyu, "Intelligent Microgrid in S. China Sea to Aid Civil, Military Development," *Global Times*, May 28, 2019, http://www.globaltimes.cn/content/1104462.shtml.

[12] Zhang Wei and Du Jianguo, "三十六计与古今战争，第一计：'瞒天过海' " [Thirty-Six Stratagems in Ancient and Modern Wars, The First Strategem: "To Cross the Sea through Deception (Idiom)"], *解放军报 [People's Liberation Army Daily]*, April 4, 2018, 4, http://www.81.cn/gfbmap/content/2018-01/04/content_196139.htm.

scores of structures that hide the presence of military systems and obfuscate their combat status. Even if adversaries detect the arrival or presence of a particular platform or weapon system, buildings and shelters on the PLA outposts deny adversaries additional access to information that might reveal the precise location and readiness of those systems.

Fiery Cross, Subi, and Mischief Reefs each have surface-to-air missile (SAM) facilities that can house a SAM battalion consisting of eight transporter-erector-launchers (TELs) as well as associated radar and support vehicles. There are two drive-in bays in each SAM TEL "garage" (20 by 22 meters, 66 by 72 feet). The buildings appear to have retractable roofs that allow a TEL for a vertically launched weapon, such as the HQ-9 long-range SAM, to drive into the garage and then elevate TEL missile tubes inside. These garages obscure the presence and operational status of the SAM system (see Figure 7). An air search or target tracking radar appears to be collocated in an adjacent radar tower which thwarts visual observation that might otherwise indicate SAM battalion readiness or intent to employ these missiles.



(Photo courtesy of *Philippine Daily Inquirer*)

(JHU/APL Photo)

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 7. Subi Reef SAM Facility, 2017 Handheld Photo (Upper Left), Satellite Image (Right) and HQ-9 Transporter-Erector-Launcher (TEL) (Lower Left)

What appear to be surface-to-surface (SSM) facilities are also located on each of the major Chinese outposts. These facilities are candidates to house SSMs like YJ-12 anti-ship cruise missiles that have reportedly deployed to the PLA bases.[13] Each suspected SSM facility consists of a four-bay SSM TEL garage (42 by 22 meters, 138 by 72 feet) and a smaller, single-bay garage (see Figure 8). Similar to the SAM facilities, SSMs in these garages can probably be fired from within the buildings, offering no external indications about their readiness.

(Photo courtesy of Philippine Daily Inquirer)

(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 8. Subi Reef SSM Facility, 2017 Handheld Photo (Top), Satellite Image (Bottom)

[13] Amanda Macias, "China Quietly Installed Missile Systems on Strategic Spratly Islands in Hotly Contested South China Sea," *CNBC*, May 2, 2018, updated January 30, 2020, https://www.cnbc.com/2018/05/02/china-added-missile-systems-on-spratly-islands-in-south-china-sea.html.

In a combat scenario, air strikes will almost certainly target PLA SSM and SAM buildings, underscoring the vulnerability of these fixed facilities. These buildings protect deployed missile systems from the harsh SCS marine environment. However, the PLA also believes that the day-to-day concealment sets conditions for conflict. In advance of conflict, enemy reconnaissance may not be able to determine the types of weapons housed in the buildings, whether each garage actually contains a TEL, or whether the systems are ready to fire. In the absence of evidence to the contrary, an enemy might assume that each garage must be occupied with a loaded, combat-ready system having the greatest capability and longest range. Alternatively, SAMs and SSMs may be dispersed, leaving the hangers empty. All of this is designed to leave an adversary guessing and, potentially, deterred from attacking.

Chinese military doctrine, such as the Chinese Academy of Military Science (AMS) *Science of Campaigns,* explicitly calls for an integral plan for camouflage, concealment, and dispersal in the execution of a "naval base defense campaign."[14] In such a defensive campaign, the PLA would likely disperse mobile ISR, missile TELs, and other weapon systems to hide in underground facilities or elsewhere in the clutter of the several square kilometers of reclaimed land. Should China's island-reefs be threatened with attack, there is little doubt that ground-mobile forces deployed to the outposts will be dispersed with enhanced CCD measures.

Specific tactical-level CCD measures exercised by the PLA to thwart enemy reconnaissance include the use of camouflage netting, smoke, obscurants, and decoys. The PLA routinely uses inflatable or hard-sided decoy equipment to draw enemy ISR and targeting away from actual equipment.[15] PLA camouflage will likely have the greatest effect on adversary electro-optic surveillance, which may also be impacted by clouds or bad weather. Space-based or airborne synthetic aperture radar (SAR) may be challenged to distinguish PLA equipment among buildings or metallic shipping containers scattered throughout the island-reefs.[16] The PLA also employs radar-reflective camouflage to defeat SAR sensors.[17]

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[14] Chinese Academy of Military Sciences, 战役学 [Science of Campaigns], ed. Zhang Yuliang et al. (Beijing: National Defense University Press, 2006), 548-553.

[15] See, for example, "保障 '暗战,'" [Safeguarding "Hidden Warfare"], *解放军画报 [PLA Pictorial]*, December 2017, http://www.plapic.com.cn/pub/2017-12/11/content_7863143.htm.

[16] Shen Hong, Cao Guohou, Ning Qiang, and Zhang Junhao, "浅析遥感技术给国防工程伪装带来的挑战与机遇" [Analysis of Challenges and Opportunities from Remote Sensing Technologies for Camouflage in National Defense Engineering], *中国地质调查 [Geological Survey of China]* 4, no. 3 (June 2017): 70-73.

[17] See, for example, Wang Songqi, Lei Yong, and Fei Sun, "防空导弹'遇上'高速歼击机" [Air Defense Missiles, "Meet" High Speed Fighter], 中国军网 [*China Military Online*], May 18, 2018, http://photo.81.cn/jypk/2018-05/18/content_8035877_9.htm.

Figure 9 shows a likely electronic warfare or ISR deployment site on Mischief Reef. Even with these vehicles so obviously exposed, the PLA uses camouflage netting to prevent a positive identification of the type of mobile system and its function. Also, note the dozens of shipping containers from the base's construction in the lower-right of the image. Hundreds of shipping containers used in construction are scattered throughout each major Chinese outpost and could provide ready cover against surveillance or air strikes for deployed mobile forces. For additional information about these deployment sites and the PLA's electronic warfare capabilities, see the SCS MILCAP study titled "Electronic Warfare and Signals Intelligence."

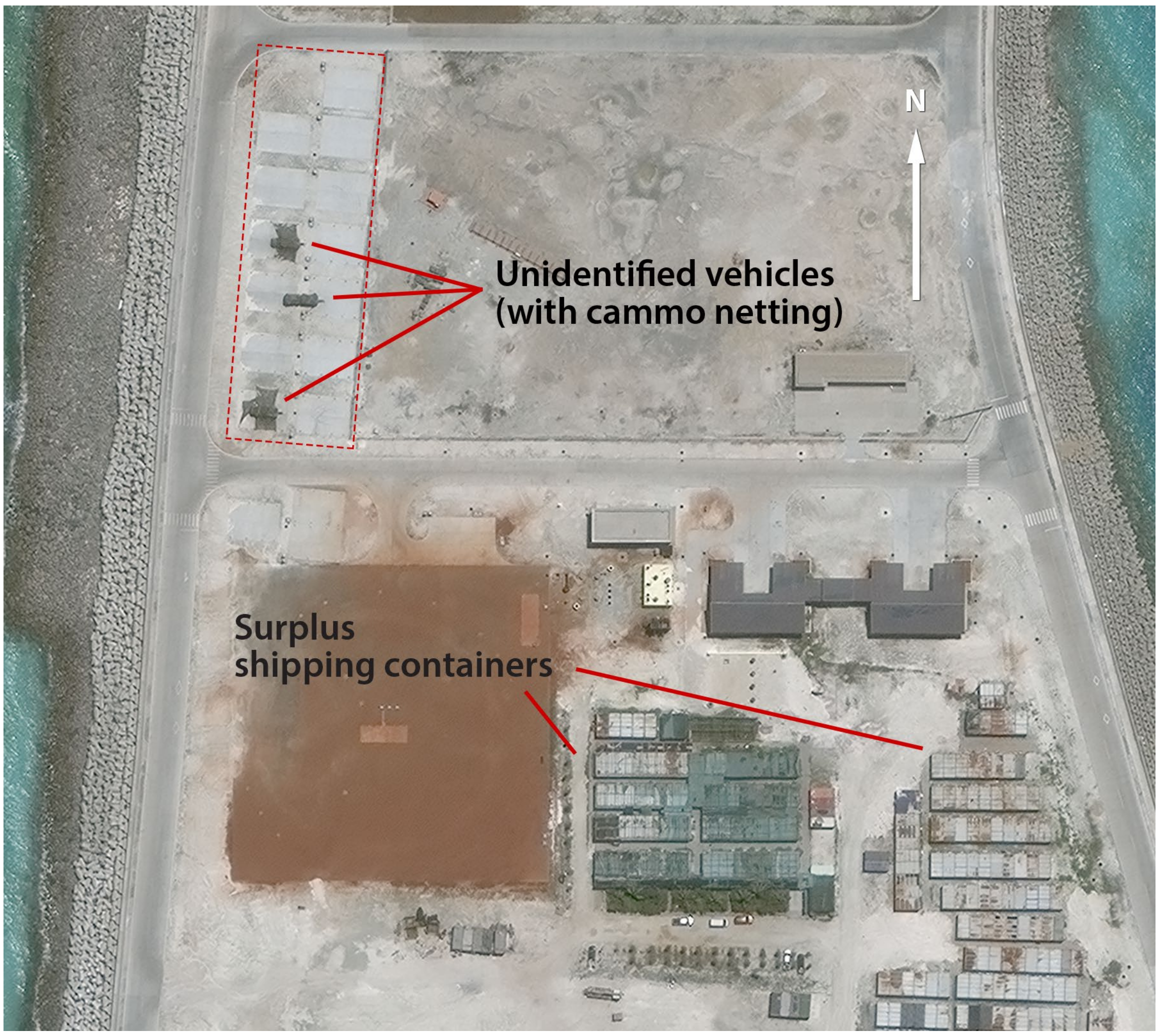

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Figure 9. Likely EW Deployment Site on Mischief Reef

Fighters, ISR aircraft, and helicopters deployed to the island-reefs may be hidden from view by the dozens of hangars at the airfields. Each airfield on the island-reefs has twenty-four fighter-size hangars to accommodate the twenty-four aircraft in a typical air force or navy fighter regiment. In addition to protecting the aircraft from the humidity and salt air of the SCS, the hangars hide the armed combat status of air defense or strike fighters from overhead surveillance. If fewer than twenty-four aircraft are deployed to any one outpost, the hangars also allow the PLA to engage in a shell game with enemy ISR. Smaller detachments of different types of aircraft may be dispersed and spread out among the seventy-two available fighter-size hangars in the SCS. Shuffling aircraft among different airfields and hangers complicates adversary targeting and increases the chances of PLA aircraft survival in the face of attacks.

Similarly, large aircraft, like H-6 bombers, support aircraft like ISR and electronic warfare aircraft, or transport aircraft can be housed in the four large aircraft hangars on both Fiery Cross and Subi Reefs or the five large hangars on Mischief Reef. The largest hangars are 68 by 64 meters (223 by 210 feet), large enough to accommodate a Y-20 transport; smaller hangars are 52 by 56 meters (171 by 184 feet), large enough to accommodate any Y-9-type aircraft. These hangars have sufficient space to unload cargo from transport aircraft out of sight of enemy surveillance. Larger long-endurance unmanned aerial vehicles (UAVs) cannot fit in the fighter-sized hangers due to their wingspans and would need to be housed in large aircraft hangers.

Helicopters may use either the large or small hangers to secretly prepare and load troops for an assault on a nearby SCS island, decreasing warning times for the targeted enemy outpost or those who might defend them. The PLA Navy version of the largest Chinese military helicopter, the Z-8, has folding rotor blades and easily fits in a fighter-size hangar. For additional information on what the PLA terms an "offensive campaigns against coral island-reefs," see the SCS MILCAP study titled "Offensive and Defensive Strike."

Figure 10 is an example of the different aircraft that might be hidden within SCS air-field hangars. This example shows the potential for how different aircraft might be placed and hidden. It does not represent a likely mix of aircraft at any one airfield. Similar aircraft would probably be grouped at one airfield due to logistics requirements centered around a particular aircraft's maintenance personnel, spare parts, and weapons stores.

For additional information on SAMs, SSMs, combat aircraft, and other weapons capabilities, see the SCS MILCAP study, "Offensive and Defensive Strike." For additional information on electronic warfare/ISR aircraft or UAVs, see the SCS MILCAP study, "Special Mission Aircraft and Unmanned Systems."

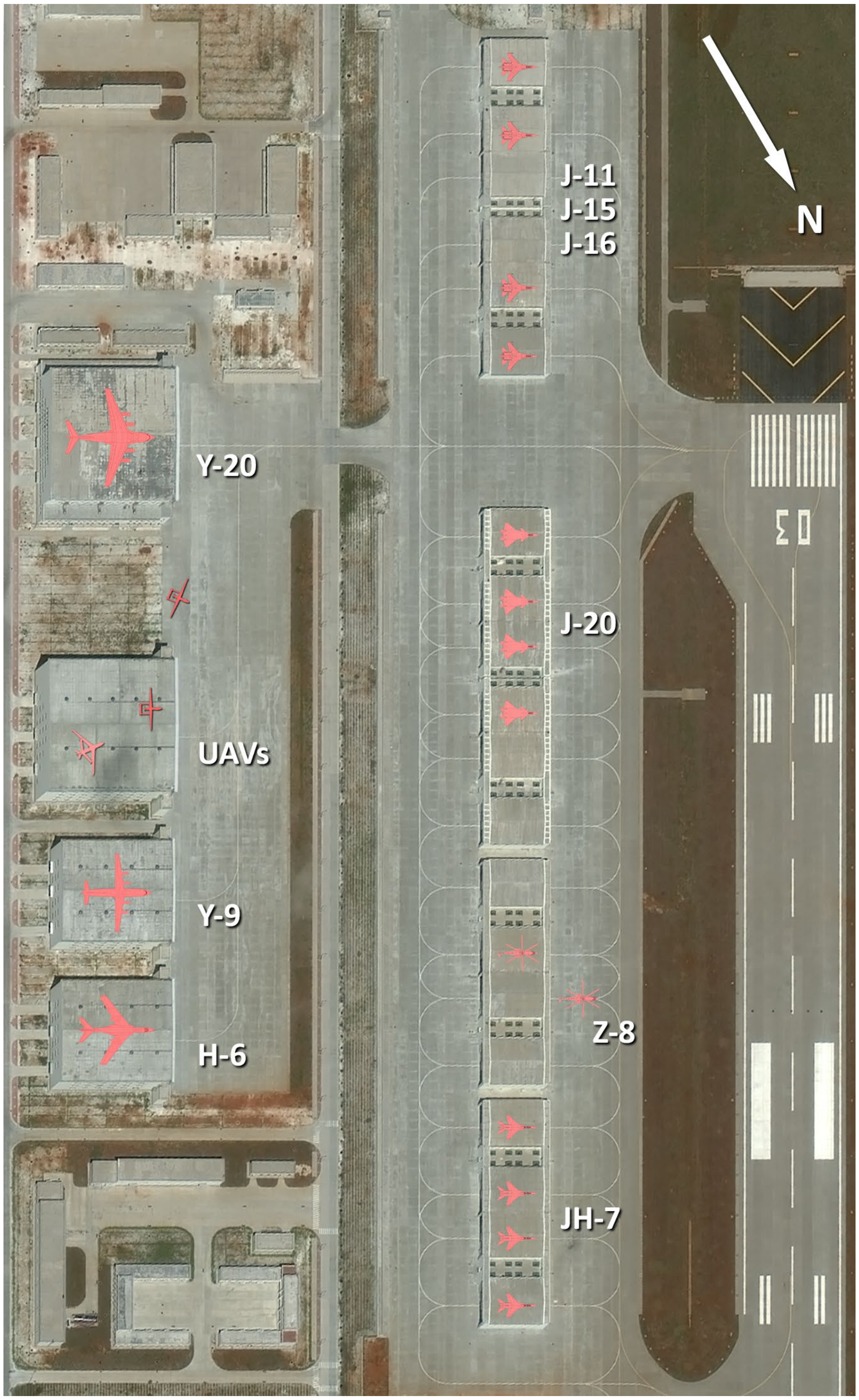

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Figure 10. Subi Reef Aircraft Parking Examples

Battlefield Environment Management

China placed significant emphasis on the management of the battlefield environment to contribute to the PLA's information power capabilities and information-centric operational concepts. The PLA Joint Staff Department Battlefield Environment Support Bureau (战场环境保障局) is responsible for military meteorology, hydrology, and other Earth sciences, as well as the PLA's positioning, navigation, and timing (PNT) programs.[18] In the 2016 PLA-wide reorganization, the bureau absorbed the former General Staff Department's Surveying, Mapping, and Navigation Bureau, as well as the Meteorology and Hydrology Bureau.[19] The PLA's Strategic Support Force (SSF) reportedly has operational responsibility for monitoring the battlefield environment and provides the Chinese joint force with mapping and geospatial information, weather data, and PNT support.[20]

Meteorology and Hydrology

What appear to be weather stations with characteristic circular meteorological instrumentation areas are located on each of the major Chinese outposts (see Figure 11). The Subi and Mischief Reef stations have probable meteorological radars housed in radomes at the station. One of the many radomes on Fiery Cross Reef may also house a weather radar, but it is not collocated with the weather station. In addition to a military meteorology contingent on the PLA bases, a small contingent of civilian State Oceanic Administration meteorologists may share these facilities.[21] These stations provide persistent, accurate measurements of atmospheric and hydrological conditions in the SCS. A refined understanding of local weather and sea conditions may significantly enhance PLA information power capabilities by increasing the performance of ISR and communications systems. For example, data on sea temperature and humidity gradients allow for detailed modeling of surface

[18] "战场环境保障局" may also be translated as "Battlefield Environment Guarantee Bureau."

[19] Wang Jun, "原总参测绘导航局局长薛贵江少将…" [Major General Xue Guijiang, Director of the General Surveying and Mapping Navigation Bureau…], *澎湃新闻 [Surge News]*, February 19, 2016, https://www.thepaper.cn/newsDetail_forward_1433620.

[20] Zhang Bo and Zou Weirong, "我军军事测绘导航建设发展迈上新台阶" [The Development of Military Surveying, Mapping and Navigation in our Army Has Taken a New Step], *中国军网 [China Military Online]*, October 15, 2017, http://www.81.cn/2017zt/2017-10/15/content_7787808.htm. See also, John Costello and Joe McReynolds, *China's Strategic Support Force: A Force for a New Era*, China Perspectives 13, (Washington, DC: National Defense University, 2018), 38, https://ndupress.ndu.edu/Portals/68/Documents/stratperspective/china/china-perspectives_13.pdf

[21] Chinese State Oceanic Administration (SOA), "'一站多能' 海洋（中心）站, 规划布局方案 ['One Station, Many Abilities' Ocean (Center) Stations, Planning and Layout Plan], SOA Notice-2016-430 (Beijing: SOA, 2016), 184.

ducting and surface wave propagation of high-frequency signals that could be used to increase the effectiveness of over-the-horizon radar or long-range communications.

(Images © 2020 Maxar/DigitalGlobe, Inc.)

Figure 11. Weather Stations on Fiery Cross (Left), Subi (Center) and Mischief Reefs (Right)

Positioning, Navigation, and Timing

22

BDS reportedly has a civilian mode and a more accurate, encrypted military mode to provide the PLA with more precise geolocation capabilities. Chinese engineers claim

[22] Deng Xiaoci, "China Completes BDS Navigation System, Reduces Reliance on GPS," *Global Times*, June 23, 2020, https://www.globaltimes.cn/content/1192482.shtml.

BDS provides decimeter-level accuracy (probably less than 1 meter/3 feet) to mobile terminals and centimeter-level static accuracy (probably sub-1-foot accuracy). BDS terminals are reportedly compatible with US, Russian, and European satellite PNT systems—GPS, GLONASS, and Galileo, respectively. BDS users can switch between the four systems.[23] If Chinese military BDS terminals can compare PNT information among the four international systems in real time, it could significantly mitigate the possibility of an adversary spoofing or jamming Beidou satellite signals in an attempt to deny the PLA satellite navigation information.

The Chinese island-reefs may host other equipment that could significantly improve PNT capabilities in the SCS. China has plans for a national ground-based network of BDS tower equipment that could increase locational accuracy.[24] Island-reef ground-based BDS augmentation may also mitigate possible interference or jamming against BDS satellite signals.

The Chinese-held island-reefs also provide locally generated, redundant PNT. Services that might verify or supplement Beidou include PNT capabilities integrated in Chinese data links or 4G/5G cellular communications systems. Each of the airfields on the major island-reefs also has what appears to be a Doppler very high frequency (VHF) omnidirectional range (DVOR) navigation beacon (see Figure 12). Even in a satellite navigation-denied environment, these VHF-band DVOR beacons enable relatively accurate navigation for aircraft and UAVs over 185 kilometers (100 nautical miles) from each of the major island-reefs.

Figure 12. DVOR Sites Adjacent to Runways on Fiery Cross (Left), Subi (Center), and Mischief Reefs (Right)

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23 Ibid.

24 Jun Shen, "Update on Beidou Navigation Satellite System (BDS)," 56th Meeting of the Civil GPS Service Interface Committee at the ION GNSS+ 2016 Conference, Portland, OR, September 12–13, 2016, http://www.gps.gov/cgsic/meetings/2016/shen.pdf.

Conclusions

Information confrontation is not limited to a competition between electronic warfare capabilities or computer information systems. Physical countermeasures—hardened infrastructure, camouflage, concealment, and deception—also significantly contribute to PLA information power capabilities by effectively denying adversaries access to battlespace information about PLA capabilities and intentions.

Hardened facilities, like the SCS island-reefs' underground storage, provide protected storage for ammunition and weapons systems. They also serve to deny an adversary information about the number and types of military capabilities that may be hidden inside. Above-ground steel tanks would be a relatively cheap and expedient way to store fuel and water on the PLA outposts. However, hardening liquid storage against potential attack under concrete and earth serves to conceal information about how much the PLA has in its island-reef fuel and water reserves. In the absence of terrain and vegetation on the Chinese artificial islands, the PLA has a variety of other CCD measures that may include hiding in or among buildings or shipping containers, employing camouflage, or deploying decoys.

Because CCD is not emphasized in US military operations, the PLA's use of deception and stratagems in modern PLA operations may be underappreciated. Quotes from the Chinese classic *The Art of War* are sometimes regarded as cliché. However, in this case, Sun Tzu's edict that "all warfare is based on deception" accurately illustrates the PLA mind-set.[25] The PLA will actively pursue their goal of information superiority by integrating CCD with other elements of information power on its SCS outposts.

Monitoring the physical battlespace and collecting weather and hydrological data from the SCS outposts also affords the PLA an information advantage. Persistent collection of weather-related data can significantly enhance the PLA's ability to manipulate and control the electromagnetic spectrum. China's seven SCS bases also likely provide local PNT capabilities that may mitigate threats to Chinese satellite navigation or allow the PLA to operate in a satellite PNT-denied environment.

PLA investments hardened infrastructure, CCD, and environmental monitoring demonstrates a Chinese informationized warfare strategy that seeks to control information within the battlespace. Countering complex Chinese systems of systems designed to control the physical and virtual information environment will require an integrated system-of-systems approach to deny PLA designs to gain and maintain information advantage in any future SCS conflict.

[25] Sun Tzu, *The Art of War*, trans Lionel Giles (London: Luzac, 1910), 3, Proquest.

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 1). 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).[26] 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 1. 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 13. The dots made up of only a few pixels in Figure 13(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 13(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 13(C) is an example that indicates the likely connection between two widely separated troposcatter terminals based on antenna pointing angles. Figure 13(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.[27]

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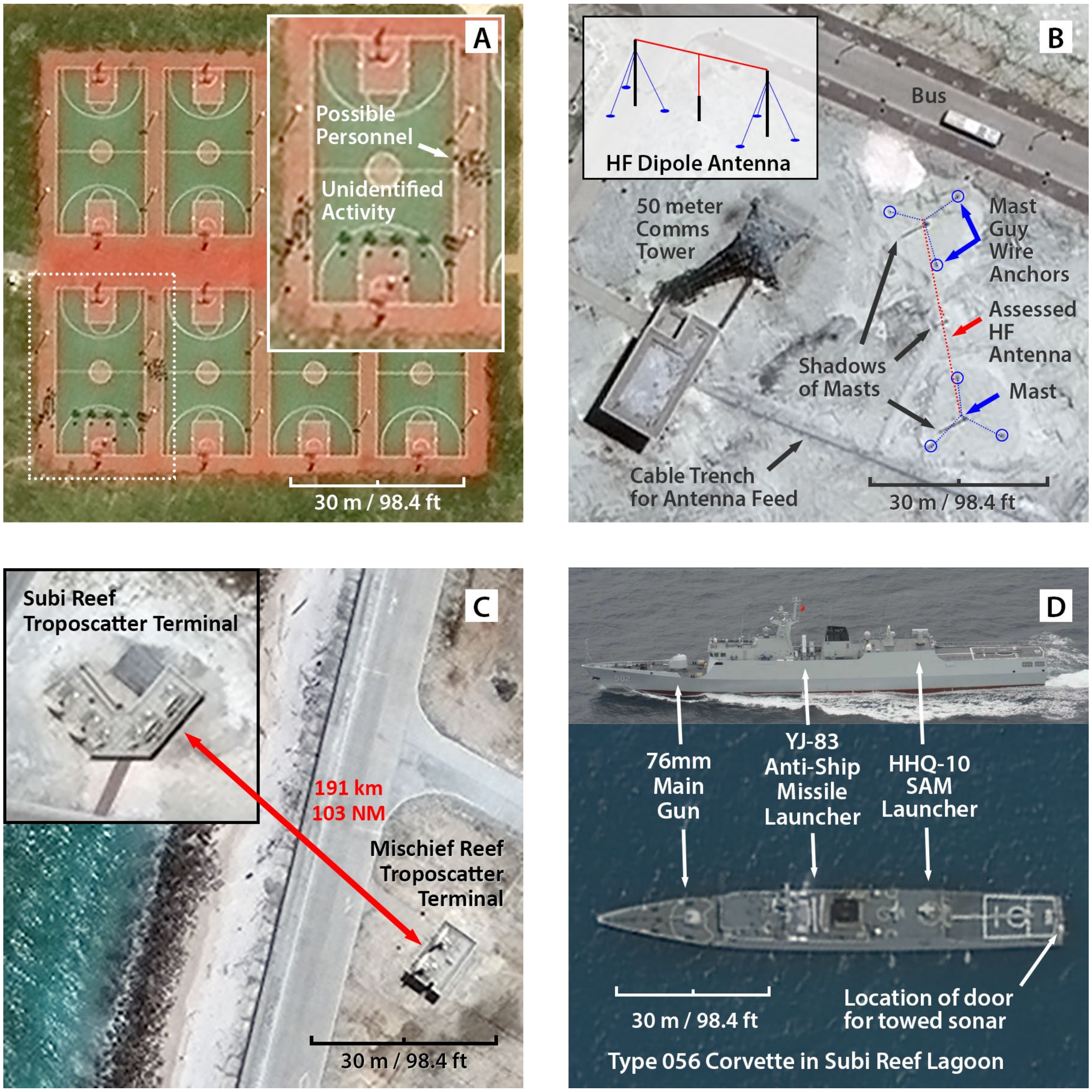
[26] Leigh Harrington, David Blanchard, James Salacain, Stephen Smith, and Philip Amanik, *General Image Quality Equation; GIQE version 5*, (Washington, DC: National Geospatial-Intelligence Agency (NGA), 2015), https://gwg.nga.mil/ntb/baseline/docs/GIQE-5_for_Public_Release.pdf.

[27] 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 13. 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

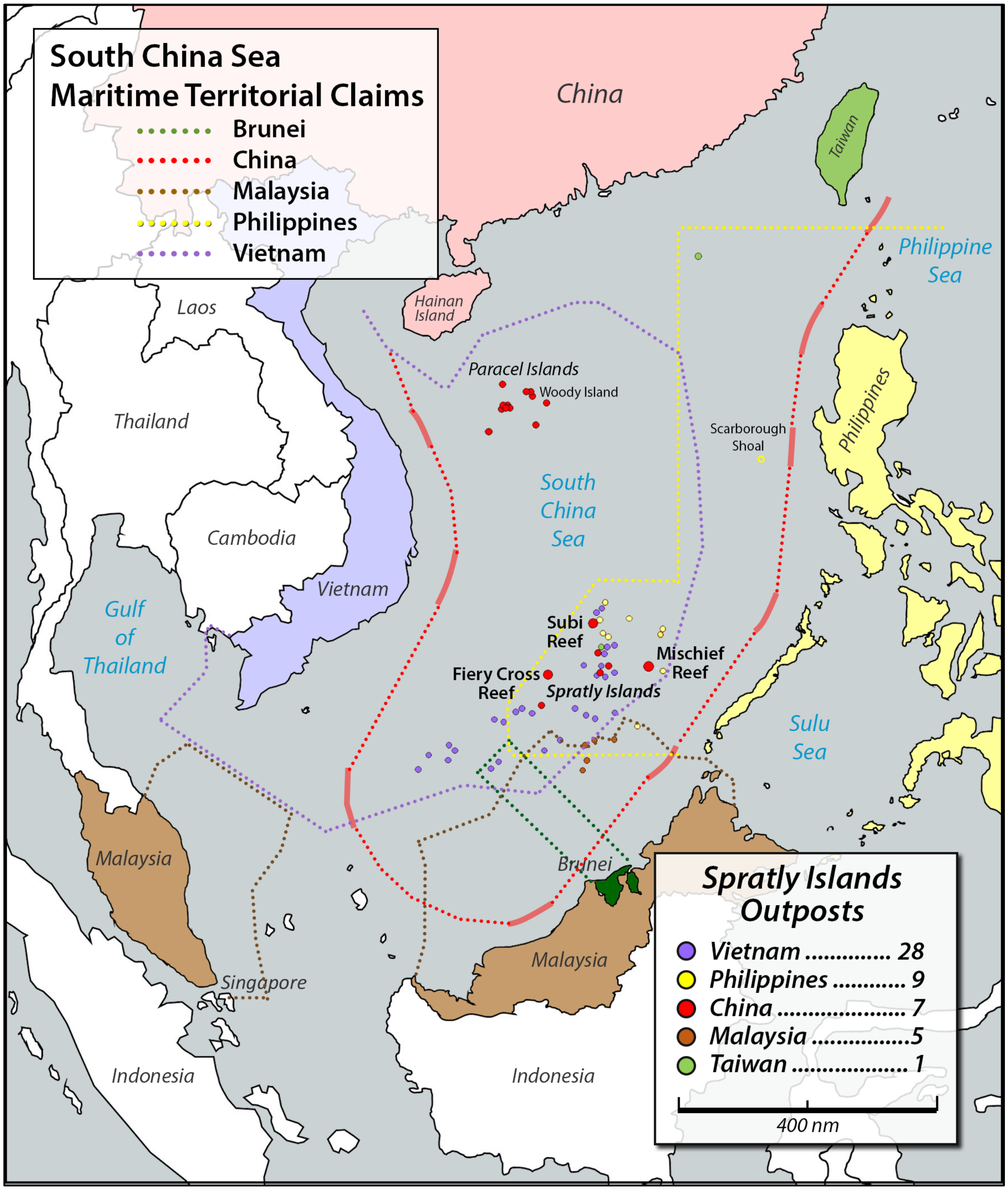
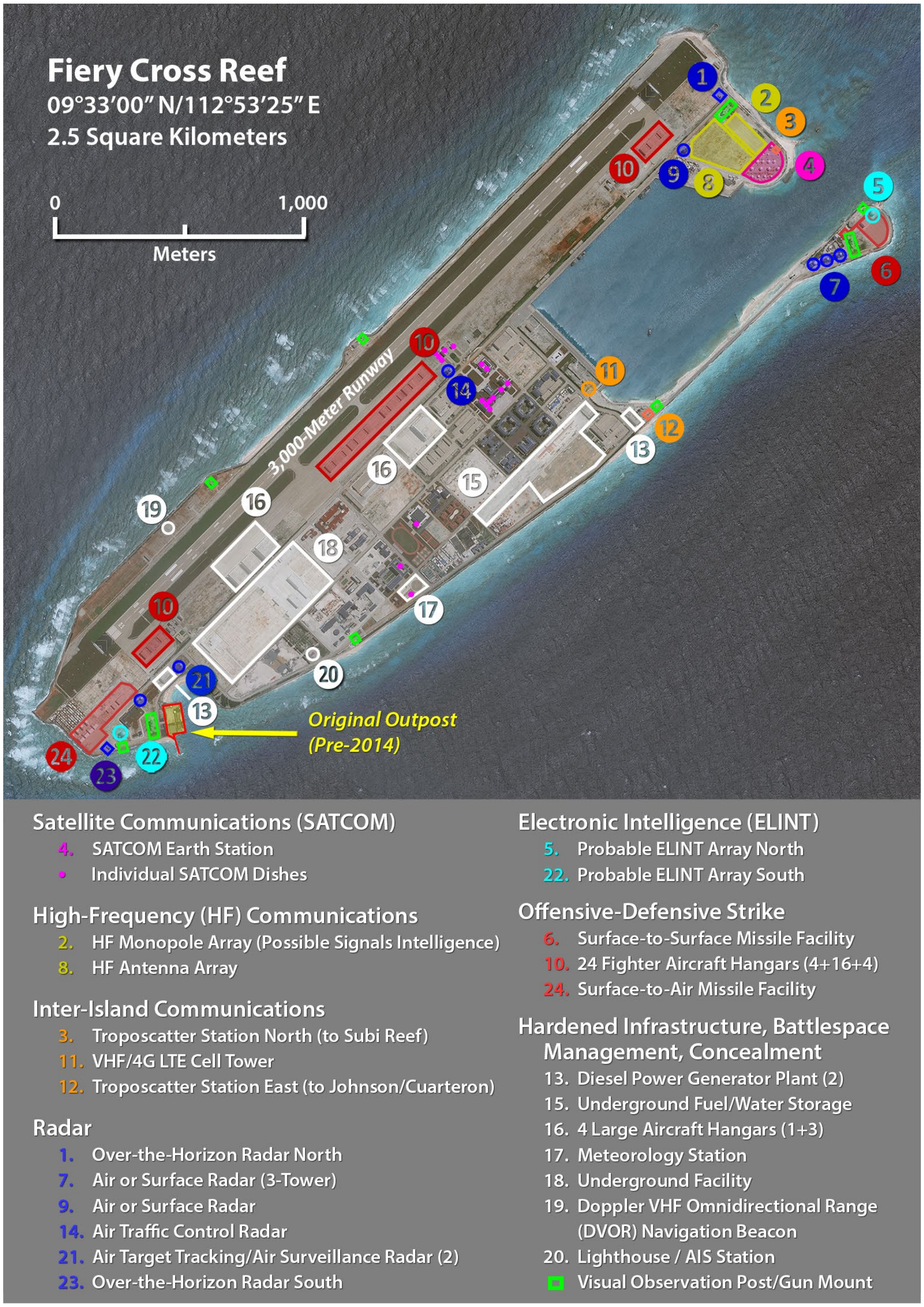


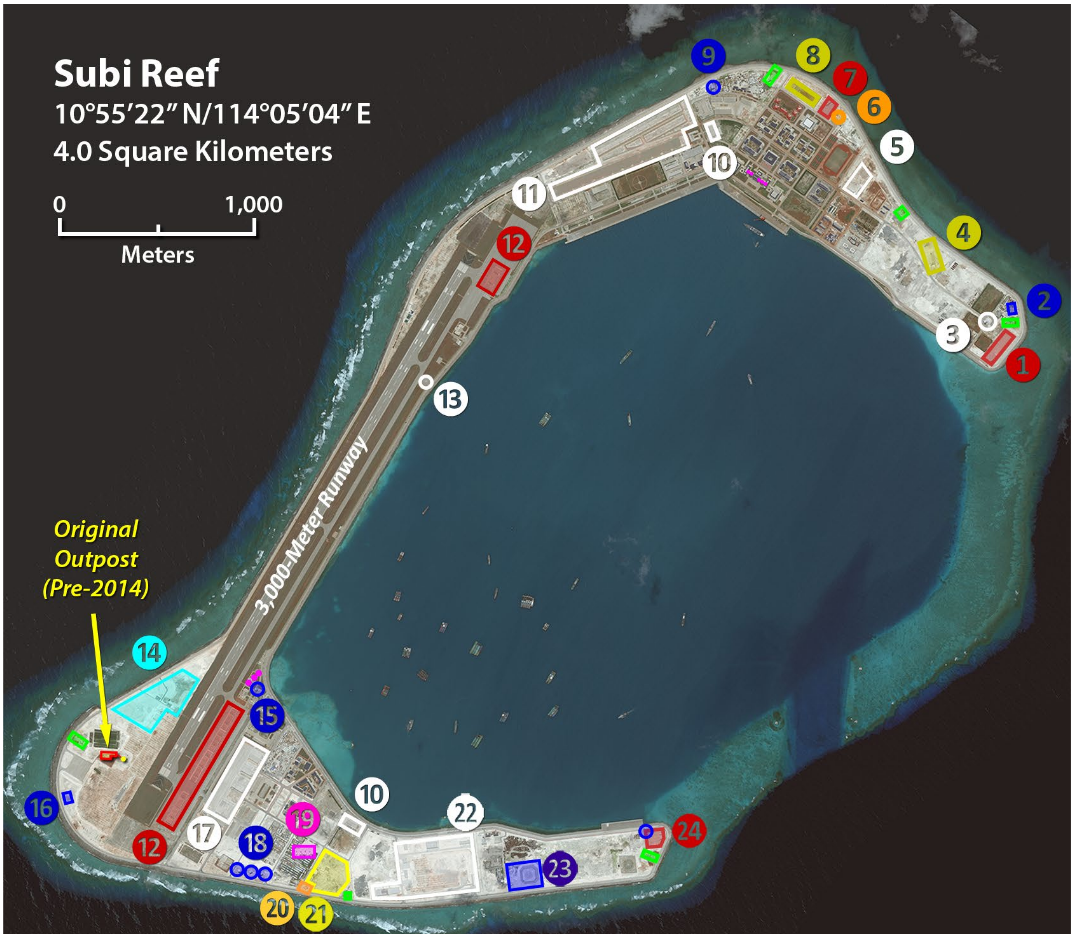
Figure 14. South China Sea Maritime Territorial Claims

Appendix C. Island-Reef Capabilities Overview Graphics



(Image © 2020 Maxar/DigitalGlobe, Inc.)

Figure 15. Fiery Cross Reef Overview



Satellite Communications (SATCOM)
19. SATCOM Earth Station
• Individual SATCOM Dishes

High-Frequency (HF) Communications
4. Possible Very-Low-Frequency (VLF)/ Low-Frequency (LF) Antenna Towers
8. HF Monopole Array (Possible Signals Intelligence)
21. HF Antenna Array

Inter-Island Communications
6. VHF/4G LTE Cell Tower
20. Troposcatter Station (to Fiery Cross & Mischief Reefs)

Radar
2. Over-the-Horizon Radar North
9. Surface Radar
15. Air Traffic Control Radar
16. Over-the-Horizon Radar South
18. Air and/or Surface Radar (3-Tower)
23. VHF Counter-Stealth Radar

Electronic Warfare / ELINT
14. Mobile System Deployment Area

Offensive-Defensive Strike
1. Surface-to-Surface Missile Facility
7. Surface-to-Surface Missile Facility
12. 24 Fighter Aircraft Hangars (4+20)
24. Surface-to-Air Missile Facility

Hardened Infrastructure, Battlespace Management, Concealment
3. Lighthouse / AIS Station
5. Meteorology Station
10. Diesel Power Generation Plant (2)
11. Underground Fuel/Water Storage
13. Doppler VHF Omnidirectional Range (DVOR) Navigation Beacon
17. 4 Large Aircraft Hangars
22. Underground Facility
■ Visual Observation Post/Gun Mount

Figure 16. Subi Reef Overview

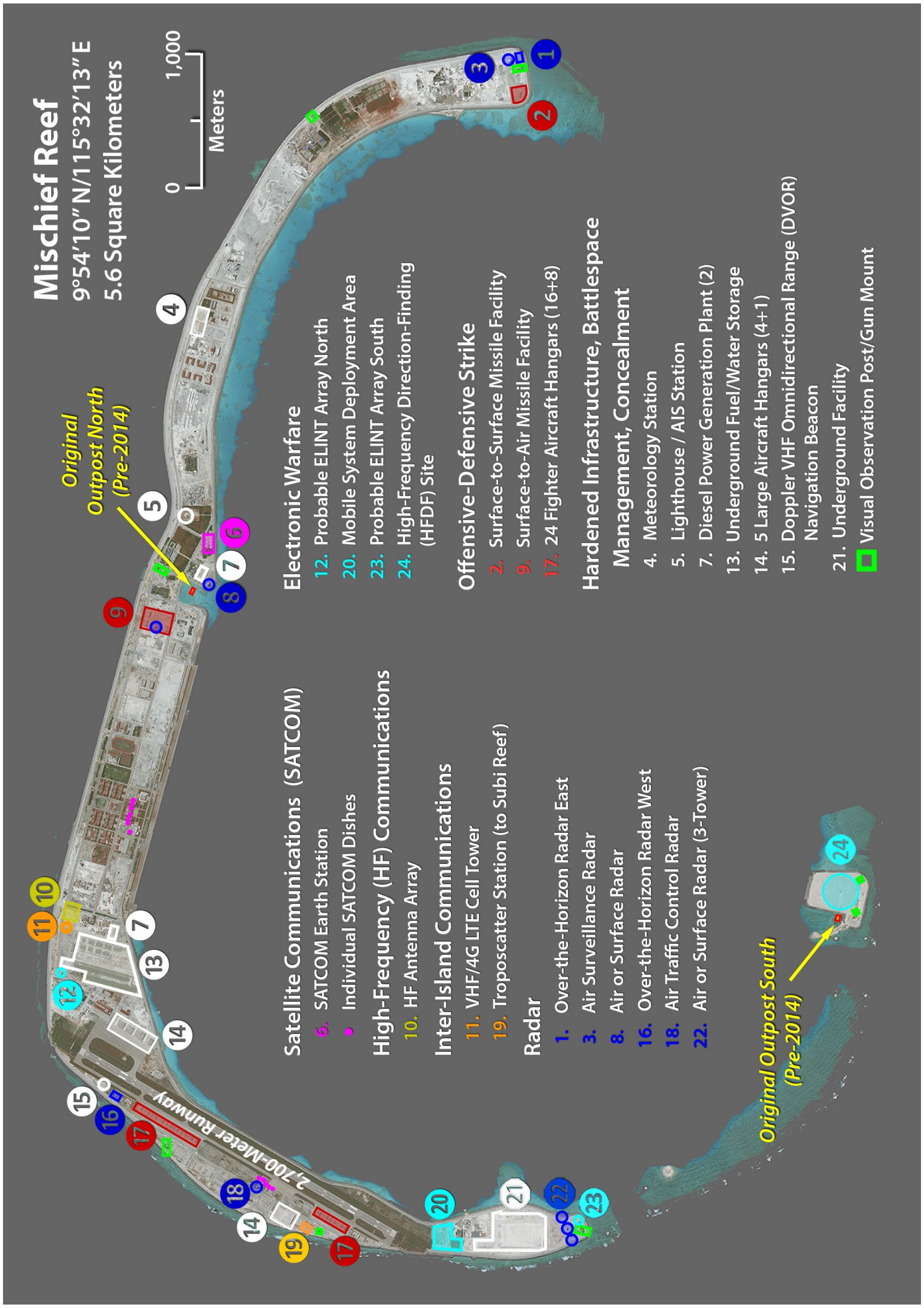


Figure 17. Mischief Reef Overview

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 2

Table 2. 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
			S	2-4 GHz
SHF	Super-high frequency	3-30 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 the 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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