

China's Weaponization of Dual-Use Research Vessels for Undersea Data Dominance

OCTOBER 2026

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Introduction

Authoritarian states are increasingly **targeting** the undersea infrastructure that connects the United States with its allies and partners. From **Western Europe** to the waters surrounding **Taiwan**, Russia and the People's Republic of China (PRC) are waging a **hybrid war** campaign—one that incorporates gray zone operations below the threshold of armed conflict to shape favorable battlespace and narratives. Central to their approach are state-owned civilian academic vessels that are “dual-use.” Such civilian vessels provide plausible deniability while enabling state-level intelligence, surveillance, and reconnaissance (ISR). To assess the extent of this strategy, the Futures Lab compared Chinese research vessel behavior against a sample of 47 other nations, including the United States and Russia. Analysis by the Futures Lab of over 200 research vessels reveals that PRC research vessels spend a statistically significantly larger share of time on the high seas—outside of international legal restrictions—near critical infrastructure. Moreover, for four out of the last five years (January 1, 2020–December 9, 2025), PRC research vessels appear in the top 20th percentile of vessels active on the high seas near critical infrastructure, with a notable increase in 2024. Put simply, the Chinese Communist Party (CCP) is ramping up its surveillance of the very undersea infrastructure that it would undoubtedly seek to sabotage in a future conflict.

The PRC's dual-use research fleet poses a particular strategic risk to U.S.-allied communications and naval operations in the first island chain. Undersea fiber-optic cables carry an estimated **99 percent of data internationally**, and daily transactions are worth **an estimated \$22.4 trillion**. This level of transnational communication cannot be replaced with satellite communication in the event of degradation by the PRC due to **significant bandwidth differences** between fiber-optic and space-based communications systems. Moreover, any serious

disruption, accidental or intentional, would likely have cascading effects due largely to the wide time horizon associated with **repairs**, ranging from days to months. The impact of delays, however, is of growing concern, as repair delays are steadily increasing due to a **lack of repair ships** and a complicated, often international or opaque, permitting process. Furthermore, timely repairs could be jeopardized by the trading speed of high-risk vendor service and the risks of wartime safe passages.

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Dual-use vessels provide the PRC with more than simple information about or access to fiber-optic cables. Surveys of the ocean floor are examples of **intelligence preparation of the operational environment** (IPOE), the **analytical process** used to provide predictive intelligence about an adversary’s probable intent and likely future actions. **U.S. Navy officials** have publicly testified that the collection of temperature, salinity, and current data enables the People’s Liberation Army Navy (PLAN) to optimize sonar performance and support persistent long-range underwater surveillance. Public reporting has **documented** Chinese-flagged research vessels equipped with seabed-mapping systems such as multibeam echo sounders that can be used to map underwater terrain to support **military operations**. These dual-use survey vessels were also observed via automatic identification system (AIS) traveling in grid-like “lawnmower” patterns **associated with bathymetric surveying** to create accurate maps of the seafloor. In addition, PRC survey missions have deployed **underwater gliders and profiling floats** that extend data collection across wide areas. Europe faces a similar threat in its oceans from modern Russian research vessels, of the ocean which are equipped with **proton magnetometers** that can identify metallic seabed objects including pipelines, anchors, and wrecks. Together, these collection methods could provide advanced force options that support future military operations ranging from gray zone harassment to sabotage.

Gray zone research activities are carried out by both Russia and China, but to situate the analysis in the Indo-Pacific, the focus of this white paper is the PRC. To analyze PRC survey vessel activity, the Futures Lab leveraged AIS tracking data and spatial layers from General Atomics’ **Optix** platform for statistical analysis. The research team started by curating a dataset of more than 200 research vessels, tracking their movements from January 1, 2020, to December 9, 2025. In addition, the team created a classification framework to label persistent ambiguous activity near subsea infrastructure on the high seas (Table A2).

Applying statistical analysis, as detailed in Appendix A, the team found that PRC-flagged ships spend significantly more time on the high seas compared to

vessels registered to the United States, Russia, and 45 other nations. Additionally, an unexpected finding emerged—PRC research vessel activity near subsea infrastructure increased sharply in 2024. Two PRC-vessel case studies—the *Xiang Yang Hong 06* (向陽紅06) and the *Ke Xue* (科學號)—illustrate how this statistical pattern appears in practice. Both vessels ranked among the most active PRC platforms within the larger dataset and conducted repeated, survey-like movements near strategically significant cable systems on the high seas, including a likely ISR mission on their “**no limits**” partner, Russia, in the summer of 2024.

Protecting undersea critical infrastructure on the high seas will require the United States and its allies and partners to establish a more credible deterrent at sea. This approach should be anchored on three core goals. First, they should strengthen maritime domain awareness (MDA) and publish evidence of suspicious activity via an international counter-gray zone forum. Second, U.S. allies and partners should form a multilateral coalition of maritime law enforcement that jointly patrols near critical infrastructure to deter gray zone activities on the high seas. Third, stakeholders should invest in regional repair hubs and multinational cable repair fleets. Together, these measures would improve **deterrence by detection and exposure**, increase MDA, and build resilience against threats to critical underwater infrastructure.

Gray Zone Competition Below the Waves

Gray zone activities and campaigns represent actions **below the threshold of conflict** covering everything from cyber, mis/dis/malinformation, and maritime militia harassment to unattributed acts of sabotage. These operations achieve limited goals without the risk of escalation, but the objectives and outcomes vary. The PRC wages gray zone campaigns to expand territorial claims in the South China Sea, India, and Taiwan. The PRC’s tactics include creating **dual-use infrastructure** for forward deployment of forces via public rail systems, establishing villages in disputed areas along the border with India, and building dam infrastructure in Tibet to **control water flows** to downstream countries in the Mekong region. The PRC is also active in **building artificial islands** and directing its maritime militia to **illegally fish**, **damage coral reefs**, coordinate maneuvers, **loiter near Taiwan**, and **sabotage subsea critical infrastructure**.

In contrast, Russia conducts gray zone campaigns in Europe to test the strength of NATO, undermine European unity, and pursue territorial expansion. Moscow’s efforts range from sending drones into EU **members’ airspace** and **financing sabotage groups** to using **energy coercion** against EU members. The combined effect is a mix of coercive signaling and setting conditions for future operations.

Modern gray zone campaigns by the PRC and Russia “**advance without attacking**,” seeking limited objectives without triggering dangerous escalation

spirals. One gray zone activity less scrutinized in public and academic discourse is the use of scientific research vessels—similar to the vessel depicted in the image below—to scan the seabed and gather oceanography data that can be repurposed for military planning.



China's *Ke Xue* research vessel.

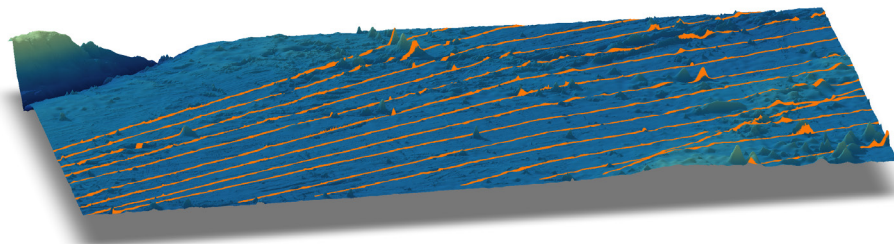
Photo: Xinhua/Zhang Xudong via Getty Images

The CCP has leveraged naval research vessels to enhance military capability for decades. Under the PRC's **military-civil fusion** doctrine, Beijing carries out civilian marine research and **national security-oriented** undersea intelligence collection. As early as 2016, the **PLA stated** that they would “leverage resources in marine resource surveys, deep-sea exploration, and oceangoing transport, to enhance the mobilization of maritime and undersea combat forces . . . and harness the mobilization capabilities of emerging domains.” As such, the organizational structure of Chinese marine research institutes falls under **CCP leadership and policy**. Moreover, and significantly for this report, marine institute survey vessels are crewed by personnel that **receive military training**. In practice, PRC-flagged research vessels are **reported to be mapping parts** of the Pacific, Indian, and Arctic Oceans, as well as **contested or rival waters** near Taiwan, Guam, Hawaii, the Philippines, Wake Island, Alaska, and the Strait of Malacca.

Under the guise of academic study, the PRC is carrying out dual-use missions that can prepare for underwater sabotage or military operations by scanning the deep seafloor. Navies around the world have long used bathymetric (underwater topography), salinity, sediment, acoustic, and hydrographic data to support

systemic analysis of the operational environment or **IPOE**. In the 1960s, early side-scan **sonars**—instruments that collect bathymetric data—were initially designed for the U.S. Naval Oceanographic Office to **support naval submarine operations**. In 2026, **research vessels collect** bathymetric (seafloor terrain mapping for underwater navigation), acoustic (underwater temperature and salinity that affect sound propagation and sonar performance), and hydrographic (currents, general depth, and seabed sediment for navigation safety) data. Once collected, this information can support submarine operations, sonar performance, cable mapping, and broader undersea warfare preparation.

Figure 1: Rendering of Underwater Landscape with Subsea Cables Using Bathymetric Scans



Source: Authors' rendering of bathymetric data from the U.S. National Oceanic and Atmospheric Administration (NOAA); orange lines denote approximate locations of fiber-optic cables.¹

Figure 1 illustrates how bathymetric data can be rendered to showcase the underwater landscape. This type of information not only supports research in oceanography, geology, and ecology; it can be used for military and other IPOE-related ends. In fact, in March 2026, U.S. Navy officials testified that the **PLAN utilizes** temperature, salinity, and current data to optimize sonar performance and support persistent surveillance. In September 2026, a Taiwan Ocean Affairs Council official was interviewed on camera by **Sky News** and described the intent of PRC research vessels near Taiwan. Deputy Minister Sung Chen-En suggested that recent surveying activity is connected to the PRC's desire to understand the area for its submarines. Chen-En described the waters as important during a PRC contingency due to the choke point for accessing the Bashi Channel. Additional reporting has documented Chinese-flagged research vessels **equipped with**

1. The bathymetric data was accessed through the NOAA Accessible Programmable Interface (API) via the R package marmap, overlaid with Optix's fiber-optic layer to illustrate the trail of cables, rasterized, and then rendered using the R package rayshader. The overlaying of the cables denoted by the orange lines in the visual is not precise, but rather based on the geolocated coordinates of the fiber-optic layer; the lines are intended only for illustrative purposes.

seabed-mapping systems, such as multibeam echo sounders, that can support military operations near undersea infrastructure. Chinese survey missions have also deployed **underwater gliders** and profiling floats that extend collection across wide areas. Notably, these dual-use survey vessels were observed via AIS traveling in grid-like **lawnmower** patterns associated with bathymetric surveying. These observable behaviors and collection methods can support future military, sabotage, or similar gray zone activities, especially on the underregulated high seas.

The **UN Convention on the Law of the Sea** (UNCLOS) provides a limited legal framework for research and survey activity at sea. The PRC ratified UNCLOS and purport to abide by it, including **Article 246**, which stipulates that marine scientific research in a foreign exclusive economic zone (EEZ) or on the continental shelf requires coastal-state consent. Under **UNCLOS Article V**, an EEZ is “an area beyond and adjacent to the territorial sea” which extends up to 200 nautical miles from where “the breadth of the territorial sea is measured.” The ambiguity of the framework stems from not clearly defining the key terminology of marine scientific research, hydrographic surveying, and military survey activity within UNCLOS. The United States **in practice views** military and hydrographic surveys as lawful in foreign EEZs without coastal-state consent. In contrast, the PRC takes the opposite view, **requiring consent** for foreign research and military survey activity in its own EEZ. Russia’s position is mixed—they require **consent for marine scientific research** in their EEZ along the northern sea route, but requirements are **less clear for military surveys**. Therefore, legal restrictions and ambiguity give way to loitering activities in disputed territory or **high seas** with minimal scrutiny. Surveying, mapping, and data collection on the high seas **are lawful under UNCLOS**, and naval and government vessels can conduct such collection openly under sovereign immunity under **Articles 95 and 96** of UNCLOS. However, civilian and state-affiliated research vessels can gather equivalent data with less visibility and greater plausible deniability. In effect, UNCLOS does not prohibit persistent activity near undersea cables.

Measuring Persistent Ambiguous Activity

In the case of possible dual-use research vessels, persistent ambiguous activity can be measured by comparing how research fleets allocate their time across strategically significant maritime locations. Previous **studies** have identified suspicious behavior by individual **dual-use research vessels**, but they have neither classified these vessels at scale nor systematically compared PRC and Russian activity with that of academic research fleets. Existing research nevertheless provides a foundation for such a comparison. Civil society organizations and think tanks have documented the institutions managing research fleets in mainland China, their **financial incentives**, and the activities

of particular vessels associated with them. Researchers have also identified indicators of potentially strategic survey activity, including grid-like **lawnmower** tracks, military-linked ownership or port visits, **disabled AIS transmissions**, and falsified location data. Related quantitative studies use vessel **movement and loitering patterns** to detect **illicit fishing**, **oil smuggling**, and **gray zone activity** near Taiwan. Building on these approaches, this study hypothesizes that the persistent use of PRC and Russian research fleets to survey the strategic underwater environment will produce a distinct spatial-temporal pattern. Specifically, *these fleets should spend a greater share of their observed time near undersea infrastructure on the high seas in comparison to other fleets of academic research vessels, including from the United States*. Unusually persistent proximity to infrastructure such as submarine fiber-optic cables—particularly in areas where legitimate scientific activity provides an ambiguous explanation—would therefore constitute evidence consistent with the exploitation of the maritime gray zone.

The Futures Lab identified vessels of interest using the **International Research Vessel Schedules & Information dataset** from the Ocean Information Center at the University of Delaware. This dataset was supplemented with **public reporting** of survey vessels studying the seafloor. Vessels thus identified were then cross-referenced against **marinetraffic.com** information to acquire vessel types and maritime mobile service identity (MMSI) numbers. This narrowed the of-interest dataset to 223 vessels identified as one of the following: fishery research vessel, research/survey vessel, dive vessel, special vessel, and fishery patrol vessel (see Table 2A for definitions).² Next, the research team queried the AIS data from General Atomics’ **Optix** platform for the 223 vessels of interest over the period spanning January 1, 2020, to December 9, 2025.³ Lastly, to enhance the AIS data, the team collected spatial layer information including **EEZs** and **high seas** from **marineregions.org**, **gas pipelines** from the **Global Energy Monitor**, **prospective critical mineral regions** as labeled by the U.S. Geological Survey (USGS), and Optix’s subsea fiber-optic cable map for processing geospatial joins.⁴

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2. The dataset includes 223 validated research vessels flagged to 48 distinct nations. Not every vessel has recorded AIS observations every year. The dataset represents the research vessels for which the team retrieved, catalogued, and validated data; it does not constitute a comprehensive inventory of the research fleets operated by these countries. Comparison groups depend on the analysis being reported. Descriptive comparisons of the PRC with all other countries use a pooled baseline of the other 47 nations. The main regression models include separate indicators for vessels flagged to the PRC, the United States, and Russia. In these models, each country’s coefficient measures its difference from the same pooled reference group comprising the remaining 45 nations, subject to data availability in the estimation sample. Discussing one country’s coefficient does not change this reference group. These estimates describe associations with vessel flags and should not be interpreted as causal effects of nationality.
 3. The timeline is based on data available to the research team at the time of writing.
 4. The joins used were cross or within spatial joins.

The PRC Exploits the High Seas for “Research”

PRC research vessels spend a statistically significant share of their observed time near subsea infrastructure on the high seas relative to most national research fleets. Scientific activity on the high seas is subject to limited international oversight, creating opportunities for states to collect valuable underwater data under the cover of dual-use research missions.⁵ The Futures Lab’s team analyzed the share of time vessels spent near critical infrastructure and found that most of the 47 (non-PRC) nations’ research vessels did not spend much time near subsea cables on the high seas.⁶ Figure 2 places the activity of the three major powers in a broader context by comparing the annual share of time that PRC, Russian, and U.S. research vessels spent near subsea cables on the high seas between January 1, 2020, and December 9, 2025.

PRC activity was especially pronounced in 2024, when seven of its research vessels ranked above the 80th percentile for time spent near subsea infrastructure on the high seas.

For most vessels in the dataset, this activity accounted for less than 1 percent of observed time each year. The three major powers, unsurprisingly, consistently ranked among the most active fleets, showcasing that competition for access to underwater data is an important component of their deep-sea research operations. U.S.-flagged vessels ranked above the 80th percentile in all five annual comparisons, PRC-flagged vessels did so in four, and Russian-flagged vessels in two. PRC activity was especially pronounced in 2024, when seven of its research vessels ranked above the 80th percentile for time spent near subsea infrastructure on the high seas. This persistent and disproportionate activity reveals that the PRC may be leveraging its research fleet for underwater data collection that may aid in the systemic analysis of terrain for sabotage or submarine operations.

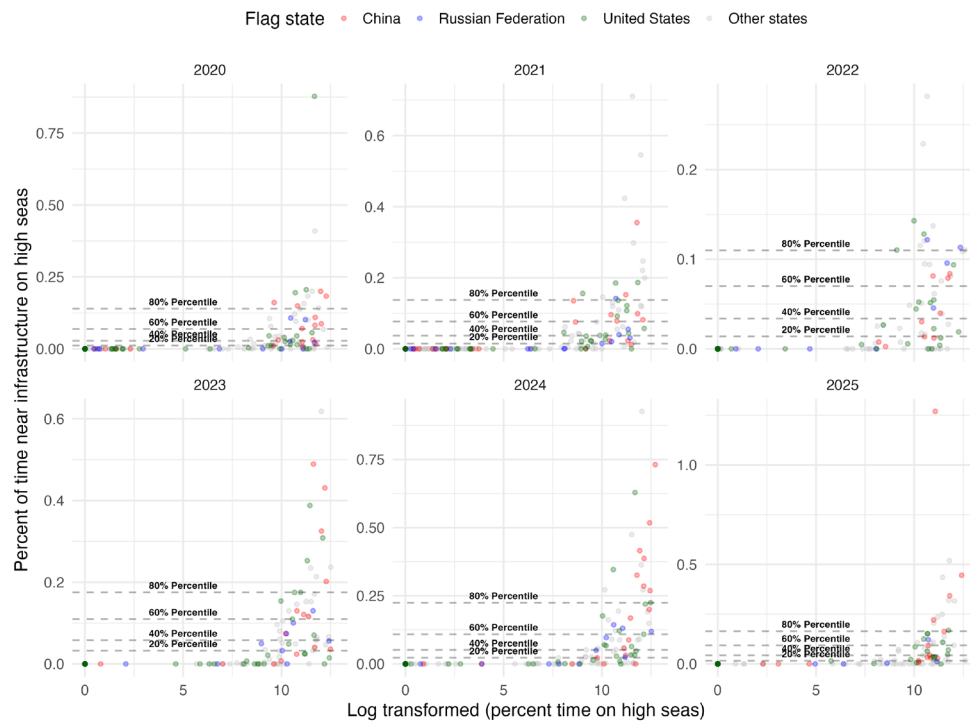
Additional regression analysis supports the conclusion illustrated in Figure 2: PRC-flagged research vessels spend disproportionately more time near subsea infrastructure on the high seas. More specifically, when compared with research vessels from the other countries represented in the dataset, PRC vessels are positively and statistically significantly associated with a greater share of observed time in these locations. As reported in Table A3 in the appendix, U.S.-flagged vessels also exhibit a positive association, although the relationship is weaker and only marginally significant. Russian-flagged vessels exhibit a negative association, though it is not statistically significant. Taken together, the year-over-year distributions and regression results identify the PRC fleet as exhibiting the

5. According to UNCLOS, the “high seas” comprises “all parts of the sea that are not included in the exclusive economic zone, in the territorial sea or in the internal waters of a State, or in the archipelagic waters of an archipelagic State.”

6. This claim is not a cumulative sum across the years. The panel regression results in Appendix Table A4, Models 4-5, showcase the year effects.

clearest and most consistent pattern of persistent ambiguous activity near subsea infrastructure on the high seas. Although these results do not independently establish the intent of specific missions, they do strengthen the inference that PRC research vessels perform dual-use data collection that may contribute to systematic seabed analysis relevant to submarine operations or infrastructure sabotage.

Figure 2: Research Vessel Time Near Infrastructure by Country



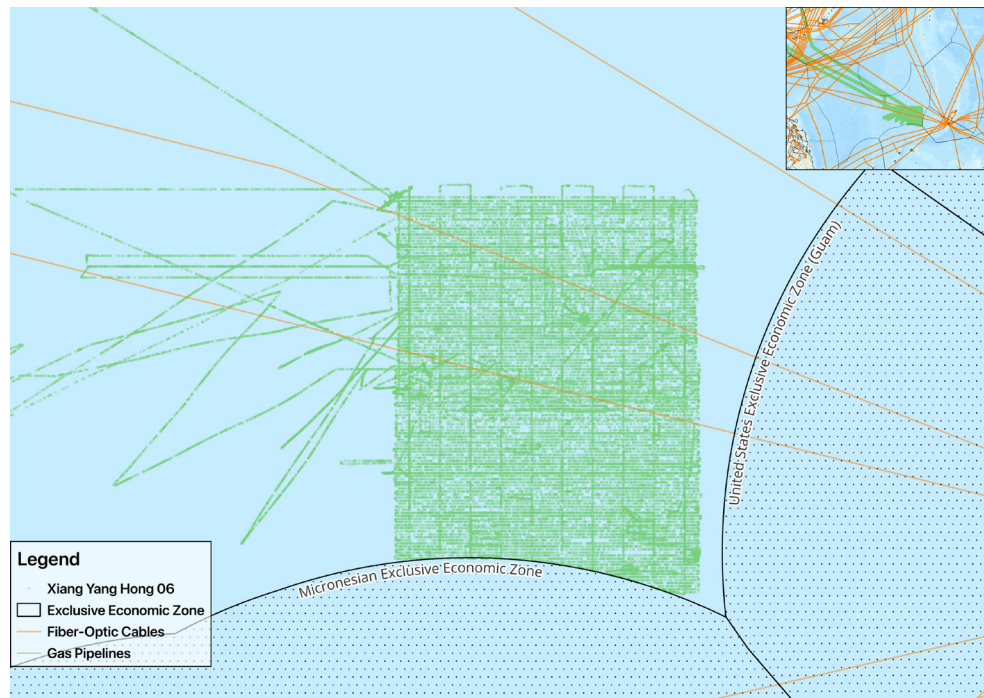
Source: Authors' analysis of AIS data from General Atomics Intelligence Optix.

While the research findings establish a broad pattern, examining individual vessel behavior reveals the strategic significance of dual-use research activity. The cases below illustrate how statistically unusual activity appears in an operational context. The Futures Lab chose the vessels *Xiang Yang Hong 06* and *Ke Xue* as exemplars because they ranked among the most active PRC research vessels near subsea infrastructure on the high seas, displayed repeated survey-like movement patterns, and operated near strategically significant cable systems that were outside areas with obvious mineral prospectivity. These two vessels thus showcase persistent, ambiguous activity by state-linked research vessels in locations where undersea data would be valuable for future military planning, surveillance, or sabotage.

Case Study 1: Xiang Yang Hong 06 near Guam

Of the research vessels identified in the 80th percentiles, the *Xiang Yang Hong 06* stood out as an outlier, falling within the 90th percentile and consequently labeled as a vessel with persistent ambiguous activity. This vessel was previously reported to **carry sonar and deep-sea sampling equipment** and had been highlighted for its journey mapping the seafloor in a **grid or lawnmower** pattern near strategic areas. What is less known to the general public is the strategic importance of the subsea cable connections it loitered near and mapped.

Figure 3: Xiang Yang Hong 06 Activity, February–May 2024



Source: AIS and fiber-optic cable data from General Atomics Intelligence Optix; EEZ locations from marineregions.org.

As shown in Figure 3, between February and May of 2024, the *Xiang Yang Hong 06* made three trips to the high seas off the coast of Guam, focusing on an area approximately 210 nautical miles from the coast of Guam in which it mapped critical infrastructure. Its survey activities covered two subsea cables: the Apricot and the ASIA-America (AAG) Cable System, the latter with connectivity to the United States. The Apricot connects six economies: Guam, Indonesia, Japan, the Philippines, Singapore, and the main island of Taiwan. The second subsea fiber-optic cable, the AAG, connects nine economies: Brunei, Guam, Hong Kong, Malaysia, the Philippines, Singapore, Thailand, the United States, and Vietnam. The *Xiang Yang Hong 06*'s mapping activities all occurred outside the United States' EEZ around Guam and on the high seas, likely to avoid **requesting**

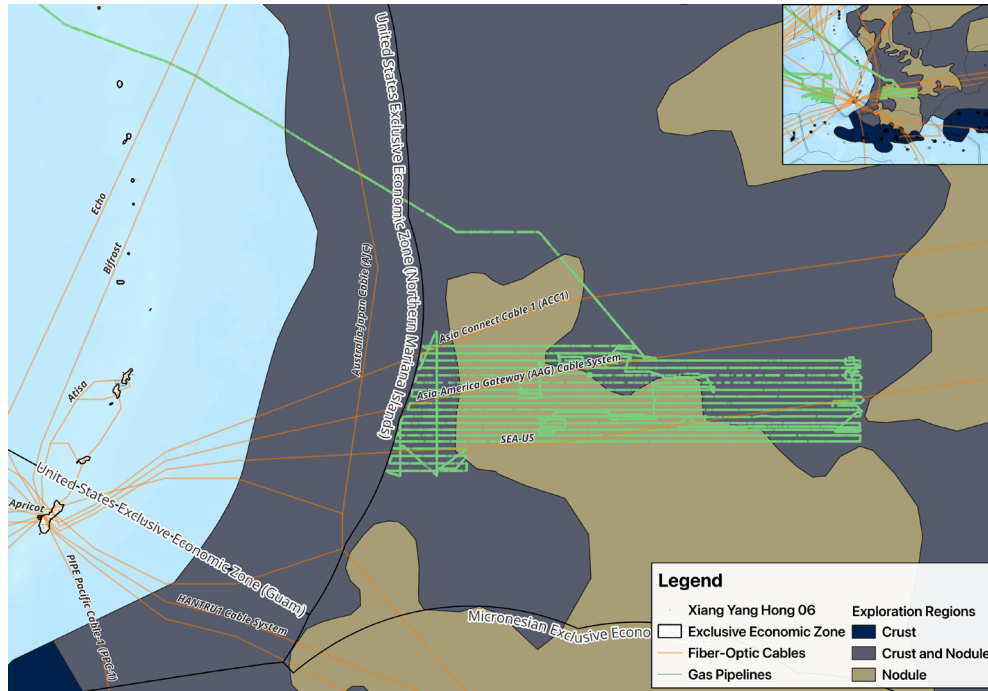
permission to map the seafloor. Both cables would be prime military targets in a military crisis between the United States and the PRC.

Importantly, these survey activities occurred *outside* the **Prime Crust Zone** (PCZ), a region in the central-western Pacific where cobalt-rich ferromanganese crusts—containing critical mineral deposits—are most likely to occur. In addition, the survey activities occurred outside the U.S. Geological Survey’s **prospective occurrence regions** layer (hereafter, exploration regions). Both the PCZ and the exploration regions comprise areas where geological and oceanographic conditions are favorable for critical mineral formation, such as seamounts, ridges, and abyssal plains characterized by low sedimentation rates, and therefore represent potential critical mineral sources. By contrast, the *Xiang Yang Hong 06*’s survey tracks are concentrated east of Guam—outside of likely mineral-rich regions—and in areas with subsea infrastructure, suggesting that the vessel’s operations are likely aligned with mapping and characterizing strategically significant undersea systems rather than with more scientific purposes.

Figure 4 represents the *Xiang Yang Hong 06*’s July 2024 journey to the east of Guam, outside the latter’s EEZ and on the high seas, covering an area that includes three cables, one under development and two operational. The survey’s July activities encompassed the **Asia Connect 1** (ACC-1), the **AAG Cable System**, and the **Southeast Asia-United States (SEA-US) Cable System**. The ACC-1 is estimated to be completed by 2028 and connects six countries and territories: Australia, Guam, Indonesia, Singapore, Timor-Leste, and the continental United States. The final cable mapped, the SEA-US, connects six countries and territories: Guam, Indonesia, Micronesia, Palau, the Philippines, and the United States.

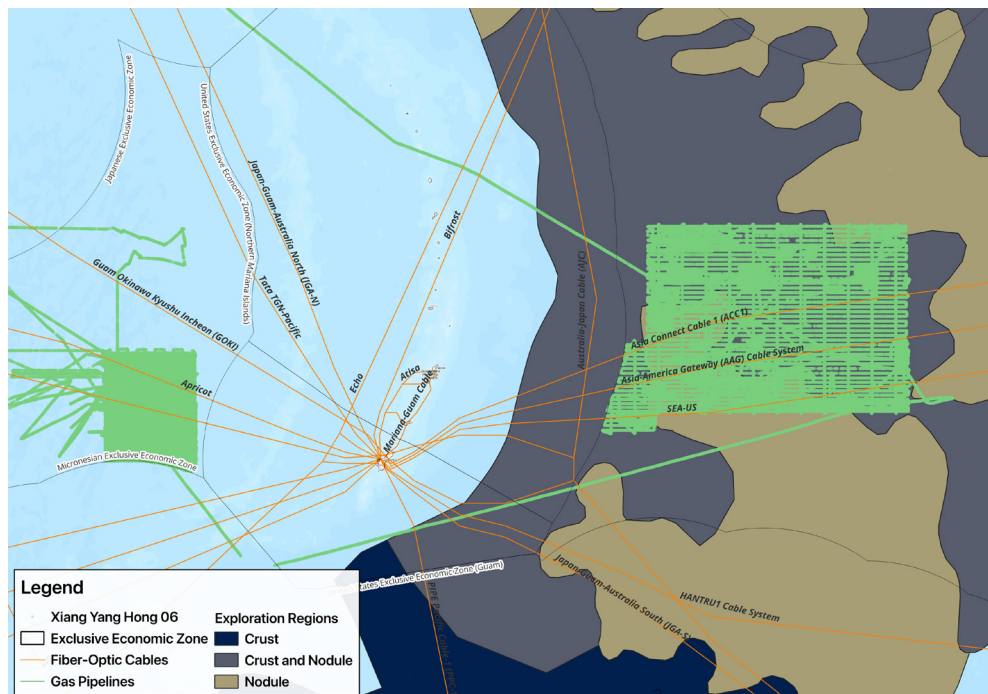
The PRC vessel’s expanded survey from August through October 2024 illustrates how dual-use research activity can combine strategic data collection with a plausible civilian explanation. As shown in Figure 5, the vessel continued exploring the region with a similar pattern, but expanding both its scope and density, likely switching from an ISR mission focused on subsea fiber cables to a civilian mission mapping the seafloor for potential mineral deposits within exploration regions, such as nodules or crust and nodule deposits. Table 1 supports this conclusion, revealing the strategic significance of this activity: None of the intersected cable systems is owned or operated by a PRC-based entity, indicating an avoidance of PRC-based systems. This increases the likelihood that the vessel was intentionally surveying the routes of foreign-built infrastructure and, furthermore, demonstrates how the PRC uses its research vessels under a scientific rationale that complicates attribution and preserves plausible deniability.

Figure 4: Xiang Yang Hong 06's Initial Pass, July 1-31, 2024



Sources: AIS and fiber-optic cable data from General Atomics Intelligence Optix; EEZ locations from marineregions.org; and exploration regions from USGS.

Figure 5: Xiang Yang Hong 06's Expanded Survey Mission, August 14-October 27, 2024



Sources: AIS and fiber-optic cable data from General Atomics Intelligence Optix; EEZ locations from marineregions.org; and exploration regions from USGS.

Table 1: *Xiang Yang Hong 06's* Activities, Subsea Cable Ownership, and Country Connections

#	Subsea Cable	Owners	Suppliers	Economies Connected	Year Online
1	Apricot	Chunghwa Telecom, Google, Meta, NTT, PLDT	SubCom	Guam, Indonesia, Japan, the Philippines, Singapore, Taiwan	2025
2	AAG	AT&T, BT, Bharti Airtel, Eastern Telecom, Ezecom, Globe Telecom, Indosat Ooredoo, National Telecom, PLDT, Saigon Postel Corporation, Spark New Zealand, Starhub, Telekom Malaysia, Telkom Indonesia, Telstra, Unified National Networks (UNN), VNPT International, Viettel Corporation	ASN, NEC	Brunei, Hong Kong, Guam, Malaysia, the Philippines, Singapore, Thailand, the United States, Vietnam	2009
3	ACC-1	Inligo Networks	NA	Australia, Guam, Indonesia, the Philippines, Singapore, Timor-Leste, the United States	Estimated 2028
4	SEA-US	GTA TeleGuam, Globe Telecom, Hawaiian Telcom, Lightstorm Telecom, Telin	NEC	Guam, Indonesia, Micronesia, Palau, the Philippines, the United States	2017

Note: The information in this table is accessible on TeleGeography's submarine cable map site for 2025. The data layer used for the classification framework was from General Atomics' Optix platform. NA represents not available.

The case of the *Xiang Yang Hong 06* reveals the dual-use survey missions near subsea cable systems on the high seas, including cables that link Guam, the continental United States, and U.S. partners across the Indo-Pacific. The vessel's movements occurred on the high seas, beyond the clear consent requirements that would apply inside a coastal state's EEZ, and, at least initially, outside areas with obvious mineral prospectivity. Considering Guam's strategic importance to the Pacific theater as both a logistics and a forward-deployment hub on the second island chain, losing undersea cable connectivity for Guam would cause significant stress to U.S. Pacific Command's (PACOM) network, particularly during a conflict, as the volume of communications in the area would expand to coordinate logistics support, troop movement, and flight deconfliction.

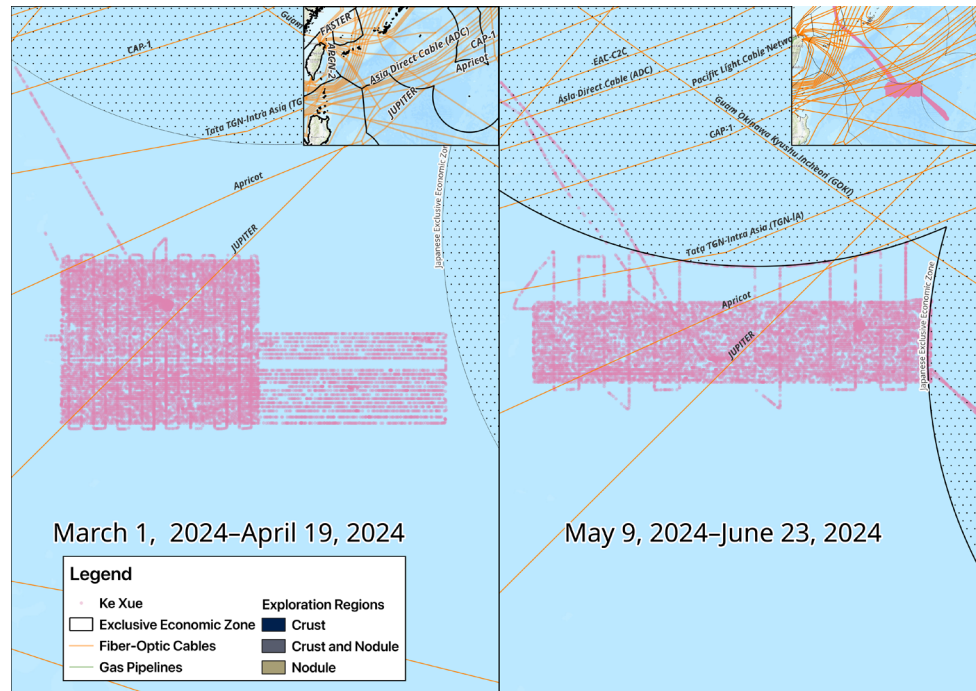
Such military coordination would be forced to share the limited space-based communications bandwidth with equally essential early-warning ISR, multidomain awareness, and fire coordination. Even during peacetime, a Chinese state-owned scientific research ship such as the *Xiang Yang Hong 06* can serve as an additional ISR asset to provide positive identification of U.S. military activities in the vicinity of Guam. The case, therefore, both offers support for this analysis's broader conclusion that PRC-linked research vessels are more active near subsea infrastructure than most other national fleets and also reveals that this activity occurs in locations where the undersea data thus collected could support future military planning, surveillance, or coercive options.

Case Study 2: The Ke Xue and the Western Pacific Cable Network

The *Ke Xue* case demonstrates how persistent ambiguous activity can extend across multiple strategically important cable corridors while remaining under the facade of scientific research. The classification framework employed here identified the Chinese-flagged vessel as exhibiting persistent ambiguous activity in 2024. **Launched in 2011**, the *Ke Xue* carries **deep-sea exploration and sampling gear** and has been referenced as a “**mobile ocean lab**.” As shown in Figure 6, *Ke Xue* began a survey-like mission in March 2024 approximately 290 nautical miles west of Japan's Okinotori Island, a geographical feature comprising approximately 108 square feet at high tide and located halfway between Taiwan and Guam, and whose legal status has been a matter of dispute for over two decades. Moreover, the *Ke Xue*'s activity occurred on the high seas, outside both the PCZ and the mineral exploration regions identified by the U.S. Geological Survey. The vessel's survey location and movement pattern therefore raise questions about whether mineral research alone adequately explains its repeated, prolonged operations near non-PRC-based subsea infrastructure.

The *Ke Xue* made two passes through the area between March and April of 2024, before returning to port and then resuming operations in the same area in May. Across these missions, the vessel's survey tracks repeatedly crossed or approached three major cable systems—the **Tata TGN-Intra Asia (TGN-IA)**, **Apricot**, and **JUPITER**—while avoiding known mineral-exploration regions. TGN-IA connects Hong Kong, the Philippines, and Vietnam and links to Tata TGN-Pacific, which extends connectivity to Guam, Japan, and the continental United States. Apricot links Guam, Indonesia, Japan, the Philippines, Singapore, and Taiwan, while JUPITER similarly connects Japan and the Philippines with the United States. These systems form part of the communications architecture linking the United States with its allies, partners, and military facilities in the Western Pacific.

Figure 6: Ke Xue's Survey Missions, March–June 2024

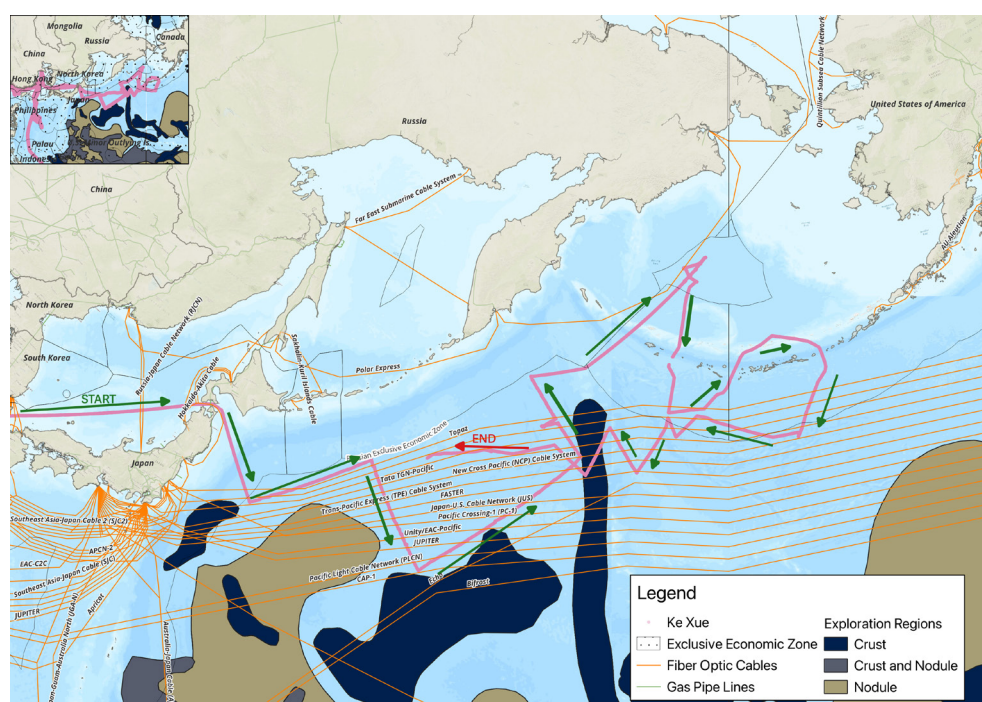


Sources: AIS and fiber-optic cable data from General Atomics Intelligence Optix; EEZ locations from marineregions.org; and exploration regions from USGS.

With these journeys, the *Ke Xue* challenged Japan's claimed EEZ near Okinotori Island and displayed survey-like movements approximately 150 nautical miles from the island. Based on the CCP's widely known hybrid warfare strategy of **advancing without attacking**, it is likely the vessel intentionally conducted marine scientific research in the area without Japanese consent, specifically to normalize PRC claims to the island—or, at least, to normalize **PRC claims that the feature is not legally an island** or continental shelf and therefore does not create a 200-nautical-mile EEZ for Japan. These missions are consistent with previously reported disputes involving PRC research vessels near Okinotori Island in **2019** and **2025**. The *Ke Xue*'s activities around Okinotori thus further illustrate how the PRC leverages its academic fleet for dual-use missions and amplify the ambiguity surrounding PRC-linked research vessel activity.

The *Ke Xue*'s subsequent activities add credence to these conclusions. Beginning in mid-July 2024, the vessel traveled north through the Sea of Japan and the Tsugaru Strait before entering the Bering Sea. As Figure 7 illustrates, the *Ke Xue* continued its trend of avoiding known mineral-exploration regions while following diagonal, survey-like tracks near at least 10 subsea cable systems connecting East Asia, Japan, and North America. This northern transit highlights the significance of the vessel's activity—the *Ke Xue* focused not on a single cable or an isolated scientific destination, but rather on geographically dispersed infrastructure corridors, repeating its earlier operational pattern.

Figure 7: The *Ke Xue*'s Northern Mission, July 15–August 28, 2024



Source: AIS and fiber-optic cable data from General Atomics Intelligence Optix; EEZ locations from marineregions.org; and exploration regions from USGS.

The eight subsea cables surveyed in the *Ke Xue*'s northern journey include **Topaz**, JUPITER (previously identified), the **New Cross Pacific (NCP) Cable System**, **FASTER**, **Pacific Crossing (PC-1)**, **Tata TGN-Pacific**, the **Trans-Pacific Express (TPE) Cable System**, the **Unity/EAC-Pacific**, and the **Pacific Light Cable Network (PLCN)**. These eight cables offer different connection points to Asia: The Topaz connects two countries, Canada and Japan; the NCP connects five countries and autonomous regions, including Japan, mainland China, South Korea, Taiwan, and the United States; FASTER and PLCN connect Japan and Taiwan to the United States; the PC-1 and the Unity/EAC Pacific systems connect Japan and the United States; the Tata TGN-Pacific links Japan and Guam to the United States; and finally, the TPE connects four countries or autonomous regions—Japan, mainland China, South Korea, and Taiwan—to the United States. As summarized in Table 2, the systems are owned by various combinations of technology and telecommunications companies, including U.S. companies such as Google, Microsoft, Meta, Amazon Web Services, and AT&T, and several major Asian carriers.

As with the *Xiang Yang Hong 06*, the PRC-linked *Ke Xue* is surveying infrastructure mostly owned by non-PRC-based entities and located outside regions with higher likelihoods of critical mineral exploration or greater scientific value. This

behavior exposes the *Ke Xue*'s use for dual-use missions, including gathering data near infrastructure and collecting scientific information.

Table 2: The *Ke Xue*'s Activities, Subsea Cable Ownership, and Country Connections

#	Subsea Cable	Owners	Suppliers	Economies Connected	Year Online
1	Topaz	Google	NEC	Canada, Japan	2023
2	JUPITER	Amazon Web Services, Meta, NTT, PCCW, PLDT, Softbank	SubCom	Japan, the Philippines, the United States	2020
3	NCP	China Mobile, China Telecom, China Unicom, Chunghwa Telecom, KT, Microsoft, Softbank	SubCom	PRC, Japan, South Korea, Taiwan, the United States	2018
4	FASTER	China Mobile, China Telecom, Google, KDDI, Singtel, TIME dotCom	NEC	Japan, Taiwan, the United States	2016
5	Tata TGN-Pacific	Tata Communications	SubCom	Guam, Japan, the United States	2002
6	TPE	AT&T, China Telecom, China Unicom, Chunghwa Telecom, KT, NTT, Verizon	SubCom	PRC, Japan, South Korea, Taiwan, the United States	2008
7	Unity/EAC-Pacific	Bharti Airtel, Google, KDDI, Singtel, TIME dotCom, Telstra	NEC, SubCom	Japan, the United States	2010
8	PLCN	Google, Meta	SubCom	Philippines, Taiwan, the United States	2022

Note: The information in this table is accessible on TeleGeography's submarine cable map site for 2025. The data layer used for the classification framework was from General Atomics' Optix platform and had both JUS and PC-1 as separate cables; on TeleGeography's site the two are shown as a single cable and are therefore sourced as one. The Japan-U.S. cable network (JUS) was retired in 2023 and is excluded from the table.

The *Ke Xue*'s activity in the Bering Sea focused on infrastructure and a U.S. military base. After leaving Russian and U.S. EEZs, the vessel began survey-like movements on the high seas near **Polar Express**, a Russian government-owned cable. This was an unexpected finding and likely reveals PRC interest in carrying out ISR on Russia's subsea telecommunications infrastructure. On its return route through the Near Islands, the *Ke Xue* temporarily stopped transmitting AIS at about 40 nautical miles east of Shemya Island, which is located at the western edge of the Aleutian Islands, about 100 miles from Russian waters, and is home to Eareckson Air Station. A central part of the third island chain, Eareckson Air Station serves as a staging ground for the United States to deploy assets to the

Asia Pacific. In the event of a conflict with the PRC, the Aleutian Islands would be operationally critical to protect sea lines of communication in the North Pacific and traffic to the Arctic. The *Ke Xue*'s northern journey built on the routes of [joint PRC-Russian patrols](#) near the Aleutians that challenged U.S. readiness in the third island chain. After masking its AIS location near Eareckson, the *Ke Xue* reappeared approximately three hours later—nearly 30 nautical miles from its last reported position—before heading south, crossing the Topaz, PC-1, and Tata TGN-Pacific cables. As such, the *Ke Xue* journey to the Bering Sea likely mapped both Russian critical infrastructure and underwater terrain near U.S. staging sites.

This was an unexpected finding and likely reveals PRC interest in carrying out ISR on Russia's subsea telecommunications infrastructure.

The *Ke Xue*'s activities highlight the national security risks posed by dual-use vessels. The undersea cable mapping draws attention to the potential for significant degradation of communication capacity between the continental United States and the U.S. military commands and allies in the first and second island chains. The U.S. military bases in Japan and South Korea are responsible for sortie generation and material readiness in a potential contingency scenario—for example, over Taiwan or the South China Sea and involving a rapid, large-scale response. Degrading subsea cables could disrupt coordination at the operational and strategic levels between forward-deployed forces and commands based in the continental United States.

In addition, the *Ke Xue* demonstrates how PRC research vessel activity near subsea infrastructure is not confined to a single geography or cable network, revealing the larger PRC strategy of undersea information dominance. In 2024, the vessel conducted repeated survey-like movements near Western Pacific cable systems linking Guam, Japan, the Philippines, Taiwan, and the United States before transiting north toward the Bering Sea and operating near cables connecting East Asia, Russia, Alaska, and North America. These movements occurred largely on the high seas and, in several instances, outside areas with obvious mineral prospectivity, making the subsea infrastructure a more plausible explanation for the vessel's operational pattern. The AIS signal gap near Shemya Island should not be overstated, but in this context, it strengthens the case for monitoring PRC research vessels as persistent ambiguous actors near critical undersea systems. *Ke Xue* thus connects the paper's statistical findings to the systematic blurring of academic research ships' scientific missions with the larger PRC goal of undersea information dominance. The vessel's tracks clearly show journeys outside known scientific collection and exploration areas, and, more significantly when considering potential wider implications, intentional proximity to infrastructure that would matter in a future crisis or conflict.

The difficulty of distinguishing legitimate scientific research activity from dual-use missions exposes an international policy and legal gap. Existing monitoring and authorization mechanisms focus heavily on territorial jurisdiction or individual incidents, not on long-term or widespread activity, particularly on the legally ambiguous high seas. This provides an opportunity for vessels such as the *Ke Xue* to operate across jurisdictions and conduct gray zone operations on the high seas largely unnoticed. In isolation, a specific survey pattern, cable crossing, port visit, or AIS interruption may have an innocuous explanation. However, when such indicators recur across multiple voyages and at strategically important locations, they can reveal a pattern of persistent ambiguous activity that incident-based monitoring fails to capture. Countering dual-use gray zone activity therefore cannot depend on proving the intent behind each mission. It must instead identify cumulative, long-term behavioral patterns, coordinate information and operational responses across different national jurisdictions, and strengthen infrastructure resilience against the disruption these missions could enable.

Building Multilateral Undersea Domain Awareness and Resilience

Damage to undersea cables could disrupt the global economy, communications, and allied military coordination. The United States and its allies and partners therefore need a multilateral approach that combines information sharing, law enforcement presence, and increased repair capacity.

This approach should focus on **deterrence by detection and exposure** and include three goals for the United States, its allies, and partners. First, they should strengthen maritime domain awareness (MDA) near critical infrastructure, particularly on the high seas, and publish evidence of suspicious PRC and Russian activity. This is needed to inform the public and researchers on new surveys and patterns that provide insight into where the PRC or Russia could cause damage to communications. Identifying the locations of suspicious activities can help prioritize unmanned surveillance and future repair efforts. Second, U.S. allies and partners should maintain a persistent maritime law enforcement presence in sensitive areas of the high seas. Third, they should invest in regional repair hubs and multinational repair fleets. Participating governments should also pool historical vessel data patterns and publish recurring assessments. These measures would help allies and partners identify patterns, coordinate responses, and deter gray zone activities.

1. Establish international countermaritime gray zone forums in Europe and the Indo-Pacific.

Ongoing efforts by states to strengthen MDA and support maritime law enforcement are fragmented, often lacking data coordination or sharing

outside of their immediate members. For example, data collected by the **Indo-Pacific Partnership for Maritime Domain Awareness** (IPMDA), formed by the **Quadrilateral Security Dialogue** to leverage space-based radio frequencies and monitor maritime illegal activities, feeds into existing regional fusion centers in Southeast Asia, the Pacific Islands, and the Indian Ocean. Meanwhile, in Europe, the **European Maritime Safety Agency** (EMSA) operates the **Common Information Sharing Environment** (CISE) to provide a framework of real-time information exchange to enhance European MDA. In North America, the United States, Canada, and Mexico established the **North American Maritime Security Initiative** (NAMSI), a trilateral forum providing a standardized operational framework for sharing maritime intelligence and conducting joint exercises and counternarcotic operations. However, these initiatives, and others, are limited to sharing between small regions or state-to-state, rather than among the initiatives themselves (see Table B1 in Appendix B).

The next step in countering the threat posed to undersea infrastructure by dual-use vessels is to gather member states and establish an International Countermaritime Gray Zone forum. The goal would be to connect countries with expertise in enhancing their MDA. Members could thus exchange regional patterns and publish PRC and Russian gray zone activities. This would bring together a fractionalized system of smaller regions into a larger grouping with enhanced MDA for all. The new framework could provide a global perspective that is currently missing.

The forum should meet twice a year. The first meeting should consist of simultaneous breakout sessions. One session should bring together EU member states and focus on detailing Russian gray zone activities in Europe, while the other should bring together Indo-Pacific states and focus on PRC gray zone activities in the Indo-Pacific. The second meeting would then be a plenary session in which EU and Indo-Pacific countries compare regional trends, jointly establish common priorities, and publish findings for the public. The organization for the meetings should be designed in the following manner:

- **International Counter-Gray Zone Working Group—Europe (ICGWG-EU):** This breakout group would be for North Atlantic Treaty Organization (NATO) and EU members to share evidence-based analysis of unclassified data from Europe, including patterns of life, execution behaviors, and signals collected from monitoring dual-use fleets. The scope of research exchanged should include the **Russian shadow fleet** and Chinese research vessels and fishing boats. The goal of this meeting would be to archive the development of Russian and PRC tactics, techniques, and procedures (TTPs) in European waters.

- **International Counter-Gray Zone Working Group–Indo-Pacific (ICGWG-IP):** This breakout group would be for U.S. allies and partners to share evidence-based analysis of unclassified data from the Indo-Pacific. Participants could include Australia, India, Japan, New Zealand, the Pacific Islands, the Philippines, South Korea, and Taiwan. Topics for analysis should include the People’s Liberation Army’s (PLA) maritime militia, expansion of territorial claims, and dual-use research vessel activities. The goal of this meeting would be to capture the developments of Russian and Chinese TTPs within the Indo-Pacific.
- **International Counter-Gray Zone Plenary Session (ICG-PS):** This would be the global plenary meeting that focuses on cross-regional sharing of case studies, lessons learned, and best practices. The session should produce a final report on current trends by region and highlight overlaps or emerging priorities for the next year. Alongside the report, the forum should publish an annual interactive online dashboard using unclassified gray zone activity data. The online dashboard should also spotlight private entities that support gray zone actors such as insurance underwriters, shipping companies, staffing agencies, banks, and repair yards. The goal of the plenary session would be to gather evidence and present trends observed in both regions to the public.

2. Form a multilateral coalition of maritime law enforcement.

Protecting critical infrastructure on the high seas will likely require coordinated joint patrols in Europe and the Indo-Pacific. Countries that share maritime regions near the PRC or Russia have a collective interest in countering gray zone campaigns to prevent damage to or disruption of communications infrastructure. Coordinated patrolling could deter Russia and the PRC; such actions by individual countries have already successfully challenged Chinese and Russian **gray zone activities** in disputed waters and **near national EEZs**.

A smaller group of capable EU and Indo-Pacific countries, therefore, should establish an International Infrastructure Security Exchange (IISX). The U.S. Coast Guard should lead the IISX, but act in coordination with capable members that share data and contribute assets near critical infrastructure on the high seas. In this manner, U.S.-led joint patrols would offer an additional means of pooling resources and distributing burden sharing to safeguard critical infrastructure.

The larger International Countermaritime Gray Zone forum should identify strategic priorities and emerging patterns, while the more focused IISX coordinates and executes operational responses. The IISX should consider the following measures:

- IISX membership should include the United States, NATO allies, and capable partner states. It should build on existing frameworks such as CISE and NANSI to share MDA data and coordinate joint air and surface patrols.
- The IISX joint patrols should track suspicious activity, establish a consistent presence, and support timely responses near critical undersea infrastructure.
- The IISX should also leverage lessons learned from the Pacific Security Maritime Exchange ([PSMX](#)), which monitors and enforces UN sanctions against North Korea, when crafting strategies to monitor and deter suspicious activity.

3. Establish collective cable repair hubs in the Indo-Pacific.

The United States, along with its allies and partners, should prepare now for subsea cable communications disruption during regional conflict. Governments have underinvested in repair capacity, leaving the Indo-Pacific in particular dependent on a small and aging fleet of specialized vessels. For example, the United States' single dedicated cable repair ship is more than 40 years old; its work is supplemented by two chartered commercial vessels. However, chartering is a short-term, expensive fix because a single repair can cost [\\$1 million to \\$3 million](#), excluding daily expenses for specialized crews.

For example, the United States' single dedicated cable repair ship is more than 40 years old; its work is supplemented by two chartered commercial vessels.

Allied and partner governments should invest in regional repair hubs and adaptable, containerized repair modules. Existing European [repair hubs](#) offer an organizational model. These hubs focus on establishing shared administrative processes and near-real-time capabilities for anomaly detection, correlation, and rapid response that are not constrained by national borders. Moreover, countries participating in repair hubs should also coordinate emergency response plans and update internal legal authorities to facilitate faster repairs. Notably, hubs are not designed to prevent gray zone activities, but instead to serve as a rapid-response capability, based on the assumption that adversaries are likely to cut cables during a contingency or conflict. Below are some suggestions:

- Repair hubs should invest in sensors that provide near-real-time data, feed anomaly-detection data into fusion platforms, and facilitate coordinated responses among allies and partners to repair cables.
- Hubs should collaborate with a vetted, contractor-owned, contractor-operated (COCO) multinational repair fleet. Contractors should undergo rigorous background and security screenings to ensure vendor

integrity. Contracted vessels should also be surveyed and cataloged in a shared database to facilitate rapid mobilization during a cable disruption. The COCO repair fleet should not trade lower cost for **untrusted vendors**.

- Countries should also develop legal mechanisms to provide flexibility to telecom providers and the owners and operators of underwater critical infrastructure. Countries that are part of regional hubs, for example, could institute internal regulatory reforms for granting repair or liability waivers and streamlining permitting processes. This would provide flexibility while repair fleets and the communication industry work to reestablish connectivity during a conflict or crisis.

Conclusion

The CCP treats its research fleet as a dual-use instrument capable of supporting both scientific missions and military preparations. Its research vessels collect oceanographic information that could support undersea intelligence gathering, submarine operations, or future attacks on critical infrastructure. This report's analysis of AIS data shows that PRC-linked research vessels spent a disproportionately large share of their observed time near critical infrastructure compared with research vessels from 47 other countries. While these findings do not establish the intent of individual missions, they do identify a persistent pattern of activity in locations where undersea data could have significant military value.

The United States and its allies and partners should act in three areas:

1. First, they should strengthen MDA and publish shared assessments of suspicious activity near undersea infrastructure.
2. Second, capable countries should join a multilateral coalition led by the United States to maintain persistent maritime law enforcement patrols on the high seas near critical infrastructure.
3. Third, they should invest in regional repair hubs and rapid-response capabilities for restoring damaged cables during a crisis.

Together, these measures would improve deterrence by detection and exposure, while also increasing MDA and resilience against future attacks. The intent of these recommendations is not to prevent legitimate scientific research on the high seas, but rather to identify persistent patterns of intelligence collection and ensure communications will survive disruptions. ■

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This report is made possible by generous support from General Atomics.

The authors wish to thank Kathleen Lord Fallon, the U.S. Coast Guard military fellow with the CSIS Defense and Security Department, for her review, feedback, and suggestions, which the team incorporated into the report.

This white paper is a policy adaptation of a conference paper submitted to the 6th Maritime Security Conference in Istanbul, Turkey. A related publication, titled “Surveying the Battlespace: How Russian and Chinese ‘Research’ Vessels Map Critical Undersea Infrastructure,” is forthcoming from the Maritime Security Center of Excellence.

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Appendix A: Research Design and Methods

Operationalizing the team’s key argument, the research hypothesis is as follows:

$$H_1 : \frac{\text{PRC/RUS time near subsea cables in the high seas}}{\text{Total PRC/RUS research fleet time}} > \frac{\text{U.S. vessel time near subsea cables}}{\text{Total U.S. research fleet time}}$$

Developing a framework to categorize activities aided in identifying expected activity and determining a baseline against which to measure potential gray zone activities. Table A1 represents the classification framework operationalized in this analysis. Thresholds are informed by public reporting of dual-use vessels and defined using distributional cutoffs, allowing vessels to be evaluated relative to expected research activity across the full dataset.

Table A1: Research Vessel Classification Framework

Activity	Conditions
Baseline	■ Share of total time tracked less than 2 percent near any infrastructure and
	■ Share of total time tracked less than 2 percent in foreign EEZ and
	■ Total share of time on the high seas and near infrastructure less than 2 percent
Persistent ambiguous activity	■ Total share of time in foreign EEZ and near infrastructure over 2 hours
	■ Share of time in foreign EEZ greater than 5 percent or
Jurisdictional ambiguity	■ Share of time in foreign EEZ and near infrastructure greater than 2 percent or
	■ Total share of time on the high seas and near infrastructure greater than 5 percent
	■ Share of time near any infrastructure greater than 5 percent

To operationalize the study’s hypothesis, this paper leverages commercial data provided through a partnership between the CSIS Futures Lab, and General Atomics Intelligence, using data from its **Optix** platform. The AIS data was preprocessed using the R programming language with the **simple features (sf)** and **arrow** packages to convert the data into the Parquet format for each year of study, reducing storage requirements. The AIS data was imported into **ArcGIS**, along with spatial layers for EEZ, high seas, gas pipes, and subsea fiber-optic cables, and then reprojected to the **Spilhaus Projection** (ESRI:54099). Within ArcGIS, the team applied buffer analysis to increase the size of the gas pipes and fiber-optic cables by one kilometer to capture **unmanned underwater vehicles** and

research vessels near the selected sites, helping to offset the imprecision of the cable locations in the layer naturally occurring over time. This was complemented by spatial joins across the layers to extract attribute features and append them to the AIS data, thereby producing binary columns for when a vessel was in an EEZ, on the high seas, in an exploration region, near gas pipes, or around subsea fiber-optic cables. Lastly, the team operationalized the classification framework in Table A1 as an algorithm in R. The final dataset was aggregated by MMSI and year and then analyzed using a regression model, as discussed in the results section and shown below in Table A3. To provide robustness checks, the team incorporated additional regressions that included a fixed year effect, revealing 2024 as a year with statistically significant activity (see Table A4).

Research and Survey Vessel Typology

The curation of the dataset was followed by gathering data from marinetraffic.com.

Table A2: Vessel Types and Definitions

Type	Definition	Source
Fishery research vessel	A specialized ship equipped with labs, scientific instruments, and gear to study marine life and ecosystems for sustainable fishing and resource management.	Damen
Research/survey vessel	Dedicated vessels used to conduct various types of research and exploration works about the seas or oceans.	Marine Insight
Dive vessel	A vessel that is used for the objective of diving into oceans. Potentially for research purposes.	Marine Insight
Fishery patrol vessel	A vessel that carries out control duties in the fishery zone outside coastal waters.	Wärtsilä

Regression Design

To evaluate the hypothesis, the authors designed the following regression formula:

$$Share\ of\ time\ near\ infrastructure_n = \beta_0 + \beta_1USA_n + \beta_2RUS_n + \beta_3CHN_n + \varepsilon_n$$

The dependent variable (Y) is defined as the share of time near subsea infrastructure. The time is calculated and estimated based on the time stamp for each observation of a unique vessel according to the vessel’s MMSI.

$$\Delta t_{i,n} = t_{i,n} - t_{i-1,n}$$

where $\Delta t_{i,n}$ is the estimated elapsed time between observation i and the previous observation $i-1$ for vessel n , and based on the indication of the vessel's presence near subsea infrastructure as:

$$I_{i,n} = \begin{cases} 1 & \text{If vessel } n \text{ is within subsea infrastructure in the high seas at observation } i \\ 0 & \text{Otherwise} \end{cases}$$

As such, Y is defined as representing the share of time by a vessel spent on the high seas and within subsea infrastructure (gas pipes or fiber-optic cables) relative to the estimated time for a given vessel present in the data.

$$Y_i = \frac{\sum_n I_{i,n} \Delta t_{i,n}}{t_{i,n}}$$

The cumulative amount of time is aggregated up to a year and then summarized as the mean—i.e., the estimated share of time the vessel n is within or crossing subsea infrastructure on the high seas.⁷

The independent variables shown as β_1, β_2 , and β_3 are binary $\in \{0, 1\}$ dummy variables for when a vessel is flagged under the United States, Russia, and the PRC. Each country's coefficient estimates the difference in the share of tracked time spent near subsea infrastructure on the high seas relative to the baseline group of vessels flagged to the remaining 45 nations.

Lastly, the error term is defined by epsilon and contains unobservable determinants of the dependent variable.

7. “Within” or “crossing” are references to the type of spatial joined use with the spatial polygon layers. The authors use “near” interchangeably.

Table A3: Flag Effects on Share of Time on the High Seas and Near Infrastructure

Dependent variable: log transformed percent of time on high seas near infrastructure

U.S.-flagged	0.013* (0.007)
Russian-flagged	-0.005 (0.010)
Chinese-flagged	0.031*** (0.008)
Constant	0.027*** (0.004)
Observations	1,177
R ²	0.015
Adjusted R ²	0.013
Residual Std. Error	0.095 (df = 1173)
F Statistic	6.038*** (df = 3; 1173)

Note: * p < 0.1; ** p < .05; *** p < .01. Not every vessel had an AIS signal for each year.

The research team ran additional robustness checks to correct for heteroskedasticity using robust standard errors, fixed effects (FE), random effects (RE), and clustered effects. The results showed that Chinese-flagged vessels continued to be statistically significant at the 0.05 level, while the significance of U.S.-flagged vessels drops and returns depending on the additional model (see Table A4). Taken together, these models lend partial support to the initial research hypothesis that PRC- and Russian-linked research vessels are being used for dual-use activities at higher rates than U.S. research vessels, with the effect being more pronounced for PRC vessels than for Russian-linked vessels.

One limitation that should be noted is that the adjusted R² indicates that the Futures Lab's model only explains an estimated 1.3 percent of variation in the data, and the model could benefit from additional relevant covariates and a larger sample size of distinct research vessels.

Table A4: Robustness Checks for Flag-State Effects on High Seas Infrastructure Exposure

Dependent variable: percent time on high seas near infrastructure

	Ordinary Least Squares (OLS)		Panel Linear		
	<i>OLS (HC1)</i>	<i>OLS (clustered by MMSI)</i>	<i>Pooled OLS (clustered by MMSI)</i>	<i>RE + Year FE</i>	<i>RE + Year FE (clustered by MMSI)</i>
	(1)	(2)	(3)	(4)	(5)
U.S.-flagged	0.01267* (0.00713)	0.01267 (0.01126)	0.01267 (0.01123)	0.01341 (0.01233)	0.01341 (0.01153)
Russian-flagged	-0.00492 (0.00533)	-0.00492 (0.00957)	-0.00492 (0.00955)	-0.00450 (0.01769)	-0.00450 (0.00956)
Chinese-flagged	0.03148*** (0.01110)	0.03148** (0.01528)	0.03148** (0.01525)	0.02912** (0.01310)	0.02912** (0.01478)
Year: 2021				0.00823 (0.00758)	0.00823 (0.00681)
Year: 2022				-0.00674 (0.00761)	-0.00674 (0.00595)
Year: 2023				0.01106 (0.00756)	0.01106* (0.00594)
Year: 2024				0.02672*** (0.00759)	0.02672*** (0.00908)
Year: 2025				0.01127 (0.00758)	0.01127 (0.00956)
Constant	0.02706*** (0.00319)	0.02706*** (0.00633)	0.02706*** (0.00631)	0.01779** (0.00783)	0.01779*** (0.00659)
Observations	1,177	1,177	1,177	1,177	1,177
R ²	0.01521	0.01521	0.01521	0.02300	0.02300
Adjusted R ²	0.01269	0.01269	0.01269	0.01631	0.01631
F Statistic (df = 3; 1173)	6.03811***	6.03811***	6.03811***	28.63502***	28.63502***

Note: * p < .1; ** p < .05; *** p < .01. Vessels in the models are distinct according to their MMSI. Columns reporting vessel fixed effects are identified from within-vessel variation; time-invariant flag indicators are therefore absorbed and not estimated. Clustered standard errors are clustered at the vessel (MMSI) level. (RE) stands for random effects and (FE) for fixed effects.

Table A4 reports robustness checks of the main OLS model described in the results section. Across all variants, vessels flagged as Chinese remain positive and statistically distinguishable from zero, while the U.S. and Russian-flagged vessels are not statistically significant. In the baseline OLS model (Table A3), the China flag variable coefficient is an estimated 0.0315 ($p < 0.001$), and it remains significant both under heteroskedasticity-robust (Table A4, Model 1) and vessel-clustered standard errors (Table A4, Model 2) ($p \approx 0.040$) and within the random effects panel model with vessel-clustered errors ($p \approx 0.049$) (Table A4, Model 5). This consistency suggests that the direction of the China association is relatively stable, though its precision weakens under more conservative error structures. At the same time, all models have low explanatory power (R^2 and adjusted R^2 roughly 0.02 or lower), indicating that flag-state indicators explain only a small share of variation in vessel time near high seas infrastructure. These checks therefore continue to provide support but are limited. The models would benefit from relevant additional covariates and instrumental variables as appropriate for the study of gray zone activity.

Appendix B: Regional Initiatives

Table B1: Examples of Initiatives for Improved MDA and Law Enforcement Capabilities

Name	Details
Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA)	Launched at the 2022 Quad Leaders’ Summit, the IPMDA is a technology and training initiative for MDA. It utilizes commercial, space-based data—specifically radio frequency tracking and synthetic aperture radar (SAR)—to track vessels operating illicitly. The IPMDA feeds near-real-time data to existing regional fusion centers in Southeast Asia, the Pacific Islands, and the Indian Ocean.
Pacific Fusion Centre (PFC)	This center was established following the mandate of the Pacific Islands Forum to meet the objectives of the 2018 Boe Declaration on Regional Security . It brings together security analysts from across the Pacific to fuse open-source and unclassified data, sharing strategic assessments on illegal fishing, transnational crime, and climate security.
Regional Fisheries Surveillance Centre (RFSC)	The RFSC helps combat illegal, unreported, and unregulated (IUU) fishing in the Pacific. It aggregates vessel monitoring system data, AIS tracking, and aerial surveillance, sharing this intelligence with member states .
Information Fusion Centre (IFC)—Singapore	The IFC is a maritime information-sharing hub connecting navies, coast guards, and maritime agencies globally. It hosts international liaison officers from multiple countries to achieve early warning of maritime security threats, tracking piracy, contraband smuggling, and maritime terrorism.
Information Fusion Centre—Indian Ocean Region (IFC-IOR)	This center focuses on sharing “White Shipping” information (data regarding the movement of commercial, nonmilitary merchant vessels) among partner countries to build a comprehensive maritime situational picture for the Indian Ocean.
CRIMARIO and the IORIS Platform	Funded by the European Union, the Critical Maritime Routes Indo-Pacific (CRIMARIO) project developed the Indo-Pacific Regional Information Sharing (IORIS) platform. IORIS is a secure, neutral, web-based maritime coordination tool used by national and regional maritime agencies to communicate and share data at sea.
Common Information Sharing Environment (CISE)	Led by the European Union and managed by the European Maritime Safety Agency (EMSA), CISE is a data-sharing initiative designed to make European and national maritime surveillance systems interoperable. It connects over 300 different authorities across varied sectors (defense, border control, customs, fisheries, and environmental protection), providing a decentralized framework for real-time information exchange to boost unified European maritime situational awareness.
Maritime Surveillance (MARSUR)	Created by the European Defence Agency (EDA), MARSUR connects the naval operation centers of participating European nations, providing a secure, automated framework to exchange naval intelligence, track vessels, and establish a common “recognized maritime picture” across Europe’s waters.
Maritime Analysis and Operations Centre—Narcotics (MAOC-N)	This is an international intelligence-sharing fusion center established by European countries and cofunded by the European Union. It fuses maritime and aviation intelligence to track and intercept illicit drug smuggling vessels.

Joint Interagency Task Force South (JIATF South)	Operating under U.S. Southern Command, JIATF South is a multinational fusion center. It acts as an international information brokerage house, integrating radar, aerial, and maritime intelligence from the U.S. military and law enforcement.
North American Maritime Security Initiative (NAMS)	NAMS is a formalized, trilateral forum involving the maritime forces and coast guards of the United States, Canada, and Mexico. It provides a standardized operational framework for the three nations to share maritime intelligence, conduct joint exercises, and operationally coordinate to detect transnational criminal threats and ensure maritime safety across North American waters.
South Atlantic Maritime Area Coordinator (CAMAS)	CAMAS coordinates maritime situational awareness, monitors merchant shipping, and ensures the security of sea lines of communication in the South Atlantic. It also has a shared interest in countering AIS manipulation and IUU fishing.
Permanent Commission for the South Pacific (CPPS)	Comprising Chile, Colombia, Ecuador, and Peru, this regional alliance (Comisión Permanente del Pacífico Sur) shares maritime data to protect the marine biodiversity in the Southeast Pacific. In recent years, CPPS has become a vital regional forum for sharing MDA to track and counter IUU fishing fleets that operate near South American EEZs.