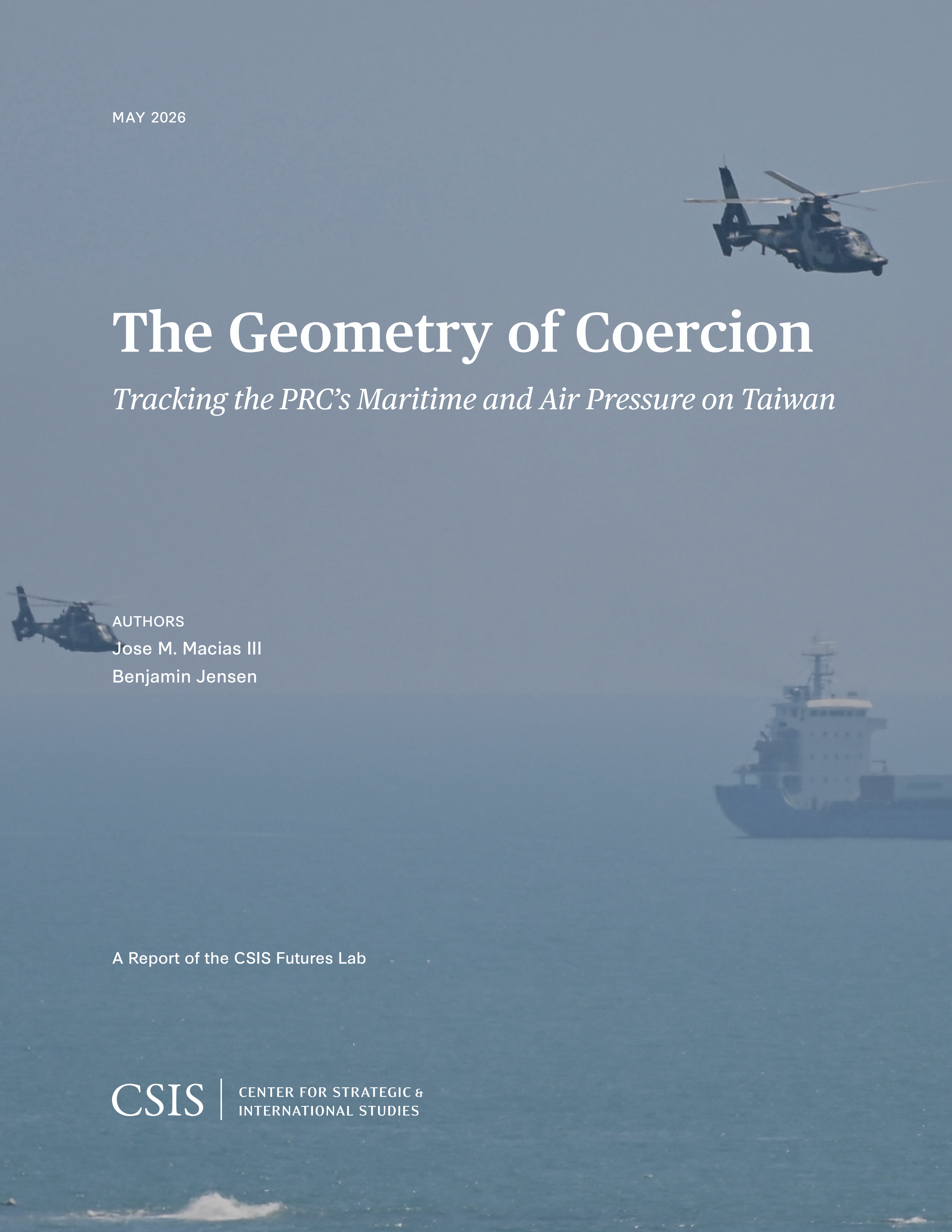

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The Geometry of Coercion

Tracking the PRC's Maritime and Air Pressure on Taiwan

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The views expressed in this brief are the views of the authors alone and do not represent their organizations.

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Contents

Executive Summary

- The People's Republic of China (PRC) is executing a sustained pressure campaign below the threshold of war. Between 2020 and 2025, average daily incursions by the China Coast Guard (CCG, 中国海警) near Taiwan's waters increased over 500 percent, with sustained presence near the median line and Taiwan's 24 nautical mile (24NM) contiguous zone boundary.[1] To counter this coercion, the United States and its allies should establish a Taiwan Pressure Observatory—a coalition-based monitoring hub that enables persistent tracking, attribution, and public reporting to reduce ambiguity and support preemptive response planning.
- PRC air activity complements maritime pressure in its cross-domain campaign. People's Liberation Army (PLA) aircraft traffic—especially unmanned aerial vehicles (UAVs) and transport aircraft—more than doubled from 2022 to 2025, with increased visits to dual use airfields/airports near Taiwan likely linked to mission support.[2] This persistent air activity strains Taiwan's ability to maintain surveillance and readiness. To offset these demands, the United States should expand Taiwan's early warning and endurance capacities through a Readiness Relief Package—including airborne early warning platforms, aerial refueling, and intelligence, surveillance, and reconnaissance (ISR) systems—to sustain monitoring without exhausting frontline assets.
- Gray zone pressure by Beijing is strategically timed and geographically targeted. The data shows that peaks in sea and air activity tend to coincide with political flashpoints and concentrate in key maritime zones near Taiwan, reflecting deliberate PRC signaling and resource attrition. Because these actions are calibrated to fall just below thresholds for international response, the United States and its allies should implement a pre-authorized

response ladder tied to thresholds and geographic incursions, thereby ensuring that specific, observable PRC behaviors trigger rapid and collective diplomatic, financial, or military consequences.

- U.S. and allied planning appears to remain reactive, not preventive. Despite clear data trends, pressure responses rely on episodic crisis management rather than steady campaigning. PRC strategy exploits this gap by wearing down Taiwan's readiness and normalizing incursions. To shift from reactionary to sustained competition, the United States and its allies should institutionalize coalition pressure monitoring and burden sharing–leveraging pooled funding mechanisms and commercial sensing contracts to expose PRC activity persistently and turn PLA persistence into a strategic liability.

Introduction

The PRC is using all of its military branches to carry out a pressure strategy against Taiwan—also known as the Republic of China (ROC)—in order to normalize PRC coercive and norm-breaking behavior. For example, to close out 2025, PRC authoritarian leader Xi Jinping ordered exercise Justice Mission-2025A to simulate a blockade and to interdict energy imports, and then stated in a follow-on speech that reunification is inevitable.[3] Between January 2020 and December 2025, the daily average of distinct CCG vessels entering Taiwan's near waters increased by over 500 percent, and daily incursions into Taiwan's second maritime security ring—between the median line and the surrounding five nautical miles from its 24NM contiguous zone boundary—more than quadrupled on average.[4] Meanwhile, publicly reported distinct PLA Air Force (PLAAF) aircraft visits to key dual use airfields/airports that may support missions near Taiwan increased over 100 percent between January 2022 and December 2025.[5] These trends reflect a growing and sustained campaign by the Chinese Communist Party (CCP) to apply pressure on Taiwan via air and maritime forces. Under the leadership of Xi Jinping, the PRC's military branches are not only increasing the frequency of their activity but also penetrating deeper into Taiwan's defensive buffer zones.

Taiwan's geographic position within the first island chain makes it not only a strategic node for U.S. and allied defense planning but also a bellwether for how the CCP might pressure other regional democracies. As Beijing ramps up maritime and air operations, Taiwan has become both a testing ground and a proving ground for the CCP's coercive playbook. What happens to Taiwan carries profound implications for neighboring countries including Japan and the Philippines—nations that, like Taiwan, seek to resist authoritarian influence in the Indo-Pacific. In this context, the

CSIS Futures Lab set out to answer a critical question: If Beijing is applying pressure, is it possible to observe and quantify that pressure systematically over time? This report introduces a novel approach to tracking and measuring PRC coercion through spatial-temporal analyses of vessel and aircraft activity. By constructing a three-ring maritime security framework and applying open-source data analysis, the researchers mapped the PRC's pressure campaign by proximity, frequency, and strategic depth—especially as it approaches the Taiwan Strait median line and Taiwan's 24NM contiguous zone boundary.

To evaluate this data systematically, this report proceeds in several parts. First, it provides strategic and historical background to frame the PRC's pressure tactics in the context of Taiwan's geopolitical significance. Then it defines a spatial framework for assessing maritime incursions and introduces the data and methodology used to measure PRC activity in sea and air domains. The results section presents findings from January 2020 to December 2025. Finally, the report introduces the Integrated Pressure Index (IPI)—a composite indicator designed to quantify daily levels of PRC pressure on Taiwan—and concludes with a set of policy recommendations focused on institutionalizing persistent monitoring, reducing Taiwan's scramble costs, and developing a pre-authorized response ladder. Recommendations include establishing a coalition-based Taiwan Pressure Observatory, funding readiness-enabling capabilities through a dedicated fast-lane assistance mechanism, and tying measurable PRC actions to preapproved diplomatic, informational, and economic consequences.

Taiwan's Enduring Strategic Relevance

In the aftermath of the Chinese Civil War and as a byproduct of U.S.-China strategic competition, Taiwan's independence is aggressively challenged by the CCP under the guise of "reunification," posing a threat both to the free people of Taiwan and to U.S. strategic interests.[6] To kick off 2026, Xi continued to threaten Taiwan, arguing that "The biggest threat to peace and stability in the Taiwan Strait is 'Taiwan independence' forces' separatist activities and . . . support for these activities" adding that, "The reunification of our motherland, a trend of the times, is unstoppable."[7] The modern-day struggle for Taiwan's independence stems from the legacy of pre-Communist China and the Nationalist government that retreated to Taiwan and other surrounding islands at the end of the Chinese Civil War in 1949.[8] This struggle and perseverance to survive is personal for the people of Taiwan, who share a mutual interest with the United States in the defense of the island's democracy.

The establishment of the ROC in 1912 followed a series of revolutionary outbreaks led by Dr. Sun Yat-Sen and the Tongmenghui—the precursor to the Kuomintang (KMT, the Nationalist Party of China)—to overthrow the Qing dynasty.[9] The ROC was intended to be the first democratic republic in Asia.[10] However, it was plagued by civil wars between various warlords and the legacies of thousand years of feudal society. In the 1930s, the survival of the ROC was seriously challenged by the invasion of Imperial Japan.[11] For the first time since 1912, different factions in China, including Mao's CCP, united under the Nationalist government as Generalissimo Chiang Kai-Shek formally declared war in July 1937 in response to the Japanese invasion.[12] After eight years of bloody battles and over three million military casualties, the ROC—as part of the Allied powers—defeated Japan in the China-Burma-India Theater of World War II.[13] The Chinese victory in the Second Sino-Japanese War (1937-1945) reversed the Japanese annexation and colonization of Taiwan (Formosa) and Penghu (Pescadores) from the First Sino-Japanese War of 1895.[14]

Peace did not last long as civil war quickly broke out between the Nationalist government and the CCP. Struggling with postwar economic and social issues while also trying to implement a democratic political system, the Nationalist government experienced a series of military defeats coupled with defection by many warlords.[15] By the end of 1949, Taiwan and a series of islands off the coast of mainland China had become the last stand of the idea of a Chinese democracy, which eventually materialized into the ROC government.[16]

In a memo dated June 14, 1950, General Douglus McArthur warned that in the hands of the Communists, Taiwan would be comparable to an "unsinkable aircraft carrier and submarine tender ideally located to accomplish Soviet offensive strategy."[17] McArthur further argued that the U.S. strategic interest would be best served if Taiwan stayed outside of the control of Communist forces–its geographic location would benefit Russian and Chinese strategy in the Indo-Pacific by providing forward bases to both and an additional fleet to Russia. McArthur also posited that in the event of a war, U.S. strike forces could interdict lines of communication and deny or materially reduce natural resource exploitation of East and Southeast Asia only if Taiwan was governed by forces friendly to the United States.[18] When the Korean War broke out soon thereafter, U.S. statesman John Dulles proposed the "Island Chain" concept, which help shaped long-term U.S. Far East strategy and continues to emphasize the importance of Taiwan on the first island chain to this day.[19]

Since mainland China fell to CCP control at the end of 1949, the battle between Taipei and Beijing has expanded from the Taiwan Strait to the diplomatic arena over which one has the legitimacy to represent China. In fact, it was the ROC–not the PRC–that joined 50 other members in founding the United Nations in 1945 and enjoyed the diplomatic recognition of many noncommunist nations for decades after.[20] However, since that time, the paradigm has gradually shifted. In 1971, General Assembly Resolution 2758 replaced Free China (the ROC) with Communist China as "the only legitimate representative of China to the United Nations."[21] International recognition of the ROC has since collapsed; even the United States shifted diplomatic recognition in 1979, though not out of principal but to drive a wedge between Communist China and the Soviet Union.[22] Despite the CCP's overwhelmingly victory in mainland China and the international arena, the very existent of a Chinese democracy on Taiwan casts a shadow over the foundation of the CCP. Taiwan is living proof that Chinese people can operate a modern democratic government that is by the people, for the people, and of the people. The survival of the ROC on Taiwan exposes the CCP's fallacy and is a real-world counterfactual to the CCP's ideological argument that democracy is incompatible with Chinese culture.[23]

The importance of Taiwan's democracy extends to Japan as security cooperation grows among the United States, Japan, and Taiwan over restraining Communist China's aggressive ambitions.[24] This was accelerated in aftermath of an August 2022 PRC exercise in which ballistic missiles fell within Japan's exclusive economic zone, setting off a security shock, catalyzing a focus on southwestern archipelago defense, and spurring calls for multilateral cooperation and planning.[25] More recently, in late 2025, Japan's Prime Minister Sanae Takaichi remarked that a Taiwan crisis could constitute a survival-threating situation that paves way for a military response.[26] Therefore, any conflict over Taiwan will likely involved the United States and its allies and partners in the region to deny Taiwan's strategic value to the CCP.

Taiwan's Enduring Vulnerability

As of 2026, the PRC's power is increasing, and it is modernizing its military capabilities to deter international intervention as it increases pressure on Taiwan.[27] Under Xi's guise of "reunification," the PRC seeks to coerce and take over Taiwan because it is (1) a free and democratic country serving as a beacon and counterfactual to authoritarianism in Chinese culture, (2) a country within the first island chain holding geopolitical importance between two major U.S. allies, and (3) commercially significant to trade and semiconductor supply chains.[28] Moreover, Taiwan could serve as a forward base for Communist China that checkmates counteroffensive operations by U.S. forces in the South China Sea.[29] Therefore, Taiwan continues to be a critical node for U.S. strategic interest and directly subject to PRC pressure to reunify and deny the United States a partner.

PRC strategy toward reunification is built on the CCP's three-wars approach: waging coercive hybrid, cognitive, and narrative wars against the people of Taiwan.[30] This pressure campaign is rooted in the CCP's historic use of gray zone campaigns against neighboring countries.[31] Gray zone campaigns present the deliberate use of coercive or subversive instruments of power by, or on behalf of, a state to achieve its political or security goals in ways that exceed or exploit gaps in international norms but remain below the threshold for direct armed conflict.[32] On land, examples include building dual-use infrastructure such as dams to control water downstream as done in Tibet, or railways to move troops and equipment for building settlements, as done in disputed territory with India.[33] At sea, gray zone tactics include island-building in the South China Sea to contest territorial claims and sending maritime militia to harass fishermen or illegally fish.[34] Gray zone activities also include instances of fishing boats from mainland China accidently or intentionally cutting fiber-optic cables, the CCG boarding or ramming into ships, and unmarked civilian fishing vessels spending unusual time near PLA Navy (PLAN) exercise zones rather than fishing hotspots.[35] Alongside the three-war campaigns, these gray zone activities are being used in Taiwan's vicinity in order to pressure the nation.

Beijing also relies on more overt military pressure and other measures that wear down Taipei's ability to respond. Military pressure activities include flying sorties into Taiwan's Air Defense Identification Zone (ADIZ) and joint PLAN and CCG blockade drills and simulations of attacks or invasions of the island.[36] Over time, the combined sustained pressure and persistent harassment by the PRC on Taiwan reduces the latter's military readiness each time it responds to or repeals PRC incursions in air or at sea. This is due both to the material wear on all components (e.g., aircraft frames, ship hulls, and mounted weapon systems) as well as the psychological wear on Taiwanese warfighters. As recently as 2024, an audit found that since 2022, Taiwan's navy had not been completing routine maintenance as scheduled in part due to operations at sea by PRC forces.[37] More importantly, the men and women making up the warfighters of Taiwan feel the pressure from persistent engagement. This is reflected through the need for longer enlistment periods to achieve proper staffing levels and sufficient training, as well as a documented sleep deficit within Taiwan's military, negatively impacting morale and the mental psychology required for fit military readiness.[38]

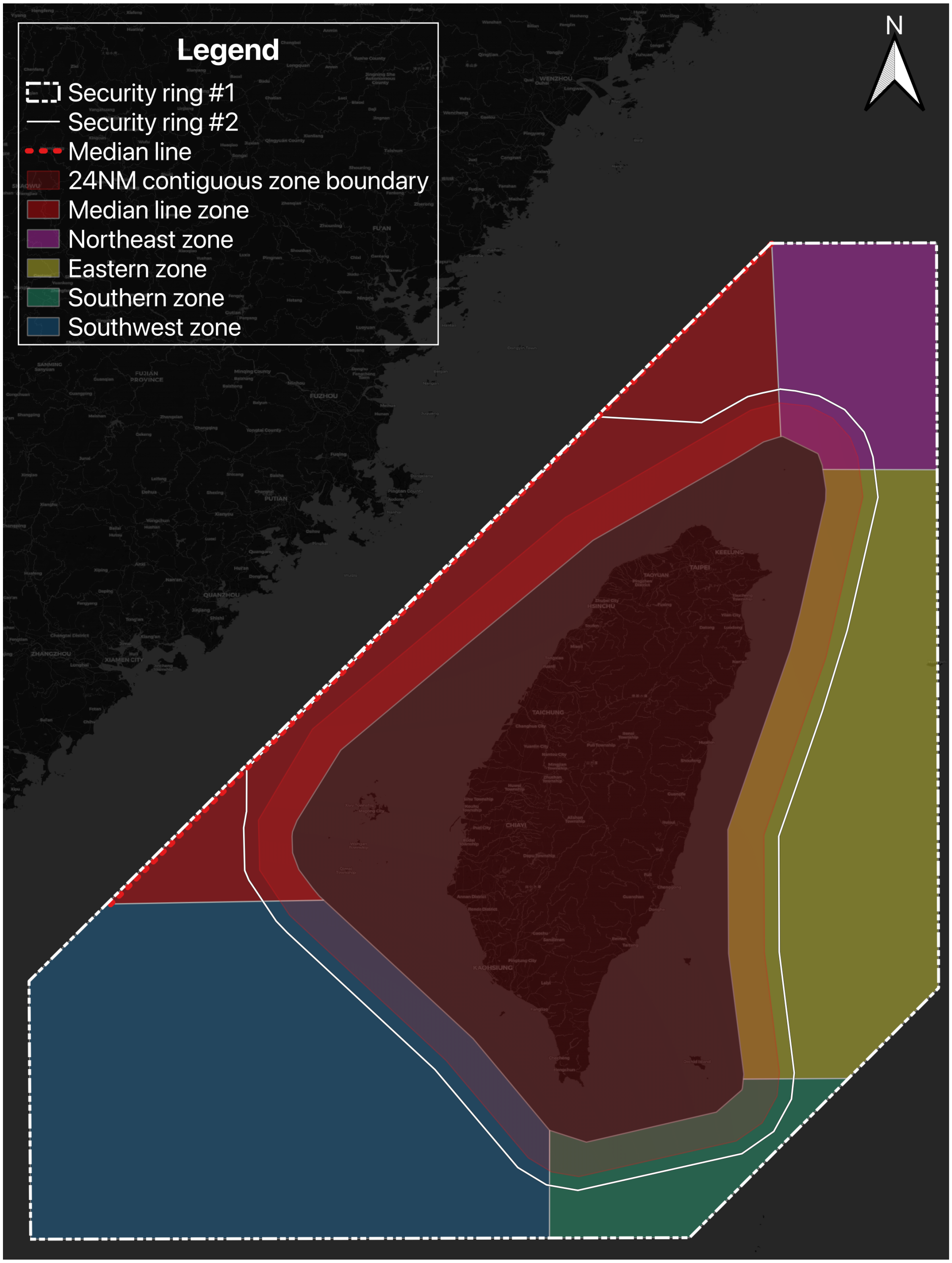
The CCP's military tactics against Taiwan are well documented and well studied by media outlets and the policy community at large. Analyses have led to the construction of new datasets on components including ADIZ violations, quantifying gray zone activities, and enabling the running of tabletop exercises that pit the United States against the PRC over Taiwan.[39] These studies add to the literature on PRC use of coercive power against Taiwan but seldom attempt to combine cross-domain data into a single analysis to measure pressure applied by Beijing. It is in this analytical gap that the CSIS Futures Lab presents its research questions: First, what are the pressure trends applied by Communist China over the years against Taiwan? Second, how sustained are these trends?

Answering these questions will help Taiwan, U.S. policymakers, and U.S. treaty allies refine their estimates to retain military readiness and optimize resources as they plan how to counter CCP gray zone and military pressure in the Indo-Pacific.

Defining Space to Analyze Pressure

To answer these questions, the CSIS Futures Lab narrowed the study of pressure in the context of Taiwan's asymmetrical defense strategy and defense in depth to sea and air domains.[40] Considering Taiwan's ADIZ, median line, and 24NM contiguous zone boundary, the lab examined sea pressure from a security ring perspective (see Figure 1). This approach weighs Taiwan's waters and conceptual airspace into defined zones to systematically monitor and assess how frequently—and how deeply—PRC forces are operating within each area via sea-based campaigns.

Figure 1: Security Rings and Defense Zones Used to Measure Pressure



Note: The ADIZ area groupings were first published by CSIS's China Power Project and are adopted here for consistency; for the original, see Lewis, "2022 in ADIZ Violations."

Source: Author analysis of Taiwan ADIZ; AIS pattern of life.

For this study, the median line and Taiwan's ADIZ represent the first security ring. As shown in Figure 1, the second security ring starts north of the island with the median line and extends approximately 33 nautical miles east before circulating 5 nautical miles from the 24NM contiguous zone boundary and extending approximately 15 nautical miles from the south to the median line. This security ring was constructed based on patterns in automatic identification system (AIS) data from CCG vessels, and rooted in the CCP's continued ambition to nullify the Taiwan Strait as international waters. Therefore, Taiwan applies a hard defense to its 24NM contiguous zone boundary, expending resources and committing personnel to respond, deny access, and prevent a change in status quo.[41]

Empirically grounding the study of the PRC pressure campaign is a crucial step to support the defense of Taiwan. Establishing an empirical baseline helps decisionmakers in Washington and other democracies visualize and describe coercion, a necessary condition for designing tailored denial-based policies to deter the CCP. The best way to confront slow, insidious pressure campaigns is to attack the plan by documenting each instance and mobilizing the resources required to undermine their efficacy.

Data, Methodology, and Empirical Strategy

To analyze pressure by sea, the research team used the software platform Optix by General Atomics Intelligence, which sources its AIS data from multiple providers, as well as historical AIS information on vessel activities.[42] Using Optix, the research team exported AIS data from January 2020 to December 2025 to track the movement of CCG vessels. The AIS data captures geographic locations of CCG vessels within the security rings. This data facilitated the creation of a spatial-temporal dataset of CCG vessels on which a point-in-polygon analysis of vessels was applied, thus detecting when vessels cross or are present within security rings over time each day. To enhance readability within the first security ring—and drawing from previous CSIS China Power Project analysis—five sub-zones were constructed: southwestern, southern, eastern, northeastern, and median.[43] In addition, the researchers employed a nearest-distance analysis from each AIS point to calculate the distance in nautical miles between each observed CCG vessel and Taiwan's 24NM contiguous zone boundary. This created a data frame in which to measure the number of vessels entering the security rings that would likely result in a dispatch or use of maritime assets by Taiwan's navy to respond and deny access.

Measuring pressure through air presents a challenge to the open-source research community, including the CSIS Futures Lab. In response, the research team narrowed their scope to air traffic to dual use airports/airfields near Taiwan by publicly reported PRC military cargo planes, UAVs, and a range of PLAAF-operated personnel aircraft. The team used air traffic as a proxy for exercise and mission sets that target Taiwan because the movement of personnel, material, and assets to military bases should be expected in the course of carrying out missions. The team used Optix and the Automatic Dependent Surveillance-Broadcast (ADS-B) data module sourced from Aireon to export air traffic.[44] The ADS-B data originated from plane transponders and provides GPS coordinates for aircraft, similar to AIS data. The key difference between ADS-B and AIS data is that the former's unique identifier is known as the aircraft's Mode S Address. For the exported data, the team drew from open-mapped and reported dual use airfields/airports used by the PLAAF and PLAN to run a point-of-polygon analysis to determine when aircraft visited these locations. This approached constructed a spatial-temporal data frame of publicly reported military aircraft per day. Of note, using this data and open-source reporting meant that no fighter jets or bombers were identified due to the proprietary encryption methods the PLA uses; the Aireon data only captures ADS-B and no other signature.

Combing both datasets serves as a starting point to answer the lab's research question and quantitatively evaluate the pressure applied to Taiwan past the standard academic and policy studies centered on ADIZ or median line violations. Based on analysis of the spatial-temporal data frame thus constructed, the CSIS Futures Lab presented two hypotheses for investigation:

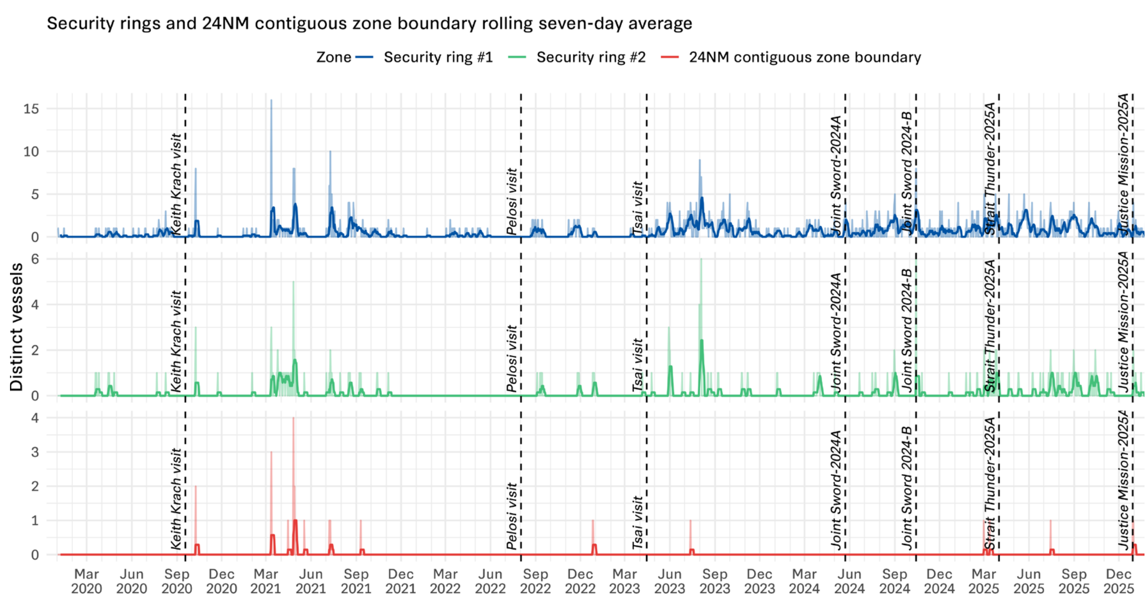
1. If the PRC is applying increasing pressure on Taiwan, then the data trends should show increased activity in sea and air over time.
2. If the PRC is applying pressure for maximum results, then trends should show sustained pressure over time rather than single point of action.

Findings

Sea Domain

Analysis reveals that the CCG is increasingly entering the first security ring over the time period captured (January 2020-December 2025). This includes passing through the Taiwan Strait median line but rarely entering the 24NM contiguous zone boundary of Taiwan.

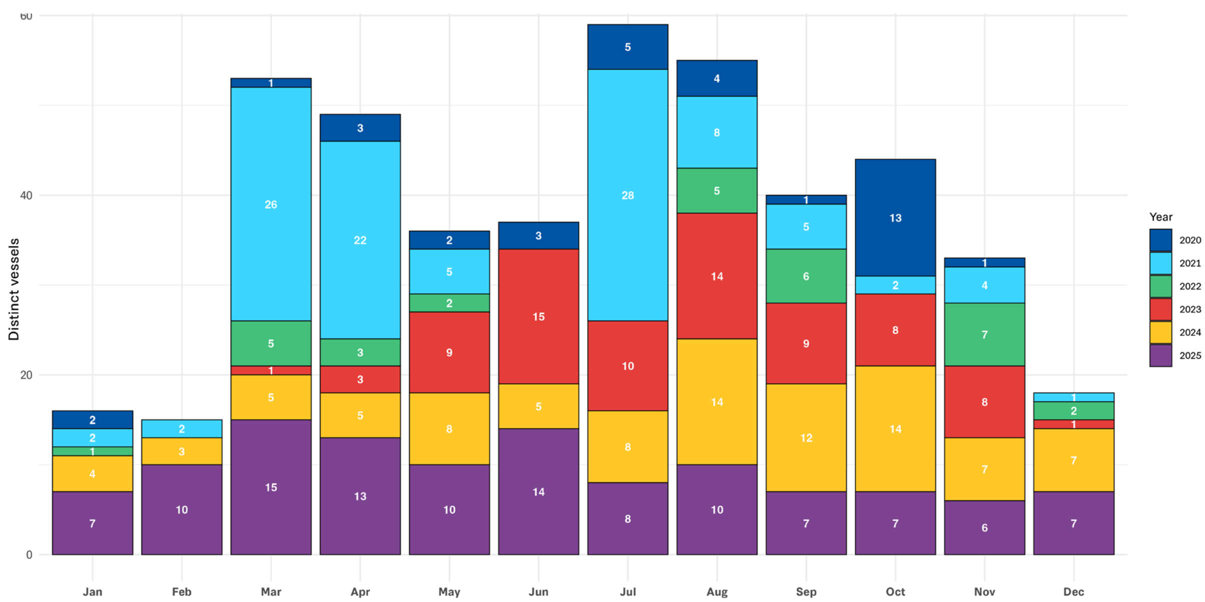
Figure 2: Sustained CCG Presence in Security Rings, January 2020–December 2025



Source: Author's point-in-polygon analysis of AIS data from General Atomics Intelligence Optix; Taiwan's ADIZ and 24NM contiguous zone boundary.

Figure 2 highlights a seven-day rolling average of the distinct daily Chinese Law Enforcement or CCG ships identified via AIS and their Maritime Mobile Service Identity (MMSI) number inside the first security ring, the second security ring, and the 24NM contiguous zone boundary between January 2020 and December 2025.[45] The clear takeaway is that, since about March 2023, the CCG has been increasingly applying sea pressure by entering the first and second security rings but staying behind—or being pushed behind by Taiwan forces—the 24NM contiguous zone boundary. A closer look at the dates of incursions implies that political signaling to Taiwan and a desire to enforce the PRC's one-China principle may be drivers of CCG actions: Following House Speaker Nancy Pelosi's visit to Taiwan (August 2-3, 2022) and President Tsai Ing-wen's visit to the United States (March-April 2023), the increased tempo has not stopped.[46]

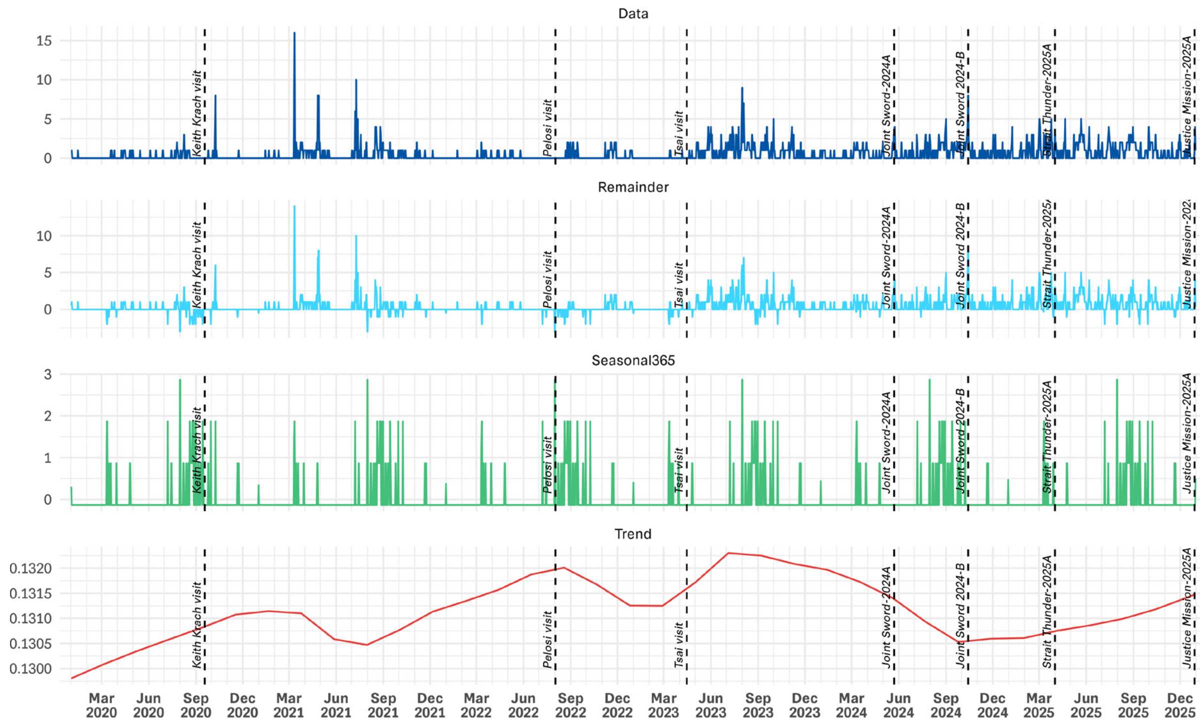
Figure 3: Distinct CCG Vessels Applying Pressure Tactics by Month, 2020-2025



Source: Author's point-in-polygon analysis of AIS data from General Atomics Optix; Taiwan's ADIZ and 24NM contiguous zone boundary.

Figure 3 breaks down the number of distinct CCG law enforcement vessels—as measured by the amount of MMSI numbers detected—found within Taiwan's first security ring by month. As displayed in Figure 3, the months with the highest counts of distinct ships from 2020 to 2025 are July, with a cumulative sum of 59, August with 55, and March with 36. Notably, each year presents varying quantities of CCG vessels entering Taiwan's first security ring. This is likely in alignment with practicing for and executing exercise drills by the PLAN. Calculating the median amount of distinct CCG within Taiwan's first security ring by month helps quantify the amount of CCG vessels sent and which months are busiest. The median calculation shows that year over year, the CCG is expected to send 9.5-10 distinct CCG vessels to Taiwan's first security ring in June, 9 in August, and at least 8 in both July and October.

Figure 4: Normalized Pressure Trends of CCG, 2020–2025



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Note: 2026 data was omitted due to missingness and skewing.

Source: Author analysis of AIS data by applying MSTL. The MSTL calculates the lowest root mean square error for trend cycle, and year windows were used for a balance between overfit and seasonality. See Kasun Bandara, Rob J Hyndman, and Christoph Bergmeir, "MSTL: A Seasonal-Trend Decomposition Algorithm for Time Series with Multiple Seasonal Patterns," *International Journal of Operational Research* 52, no. 1 (2025): 79–98, https://research.monash.edu/en/publications/mstl-a-seasonal-trend-decomposition-algorithm-for-time-series-wit/.

Figure 4 breaks down the seasonality of CCG vessel movements. The data was scaled through the Multiple Seasonal-Trend Decomposition Using LOESS (MSTL) process and normalized, which limits interpretation but highlights the trend relative to the baseline, and accounts for expected seasonal patrols and encroachments. The decomposed data reveals a higher trend line since September 2021 following a historic visit to Taiwan by Under Secretary of State Keith Krach. The visit by Under Secretary Krach was the first in 41 years by a U.S. Department of State executive leader and prompted complaints from the CCP that the United States was undermining the U.S.-China relationship and warned it would respond as necessary.[47]

After Under Secretary Krach's visit, three peaks in activity ensued: the first between December 2020 and March of 2021 in response to that visit, the second corresponding to House Speaker Pelosi's visit to Taiwan, and a third following President Tsai's visit to the United States.[48] The trend line stays elevated until PLA's operation Joint Sword-2024A (May 2024) before dropping to the levels present before Under Secretary Krach's visit, and then slowly decreasing until Joint Sword-2024B (October 2024) exercises.[49] Activity then escalates following Joint Sword-2024B through the Strait

Thunder-2025A exercise (April 2025), then further increasing to close out the year with Justice Mission-2025A exercises (December 2025).[50] This sustained pressure trend showcases the PRC's goal to change the status quo of an independent Taiwan. The PRC is attempting to illustrate control of Taiwan maritime corridors and security zones while highlighting its military capability to blockade or invade. While the rising trend at the end of 2025 is not as high as the 2023 peak, the data shows increased and sustained activity since September 2021. The decreased PRC activity after the three exercises in 2024-mid 2025 could allude to an internal measuring by the CCP on its military readiness and force capture under their "cold start"—an operational posture for rapid, high-intensity offensive operations before an adversary intervenes—or a shift toward coercing Japan.[51]

Table 1 reveals that, on average, approximately one distinct vessel entered Taiwan's first (outermost) security ring on any given day in 2025. In contrast, a CCG vessel entered the second security ring on average only once every five days in 2025. Notably, the number of distinct ships within the first ring increased by 41 percent from 2024 to 2025. In addition, one ship a day entering the first security ring in 2025 is about a fivefold increase over 2020, when incursion was, on average, a single ship every seven days.

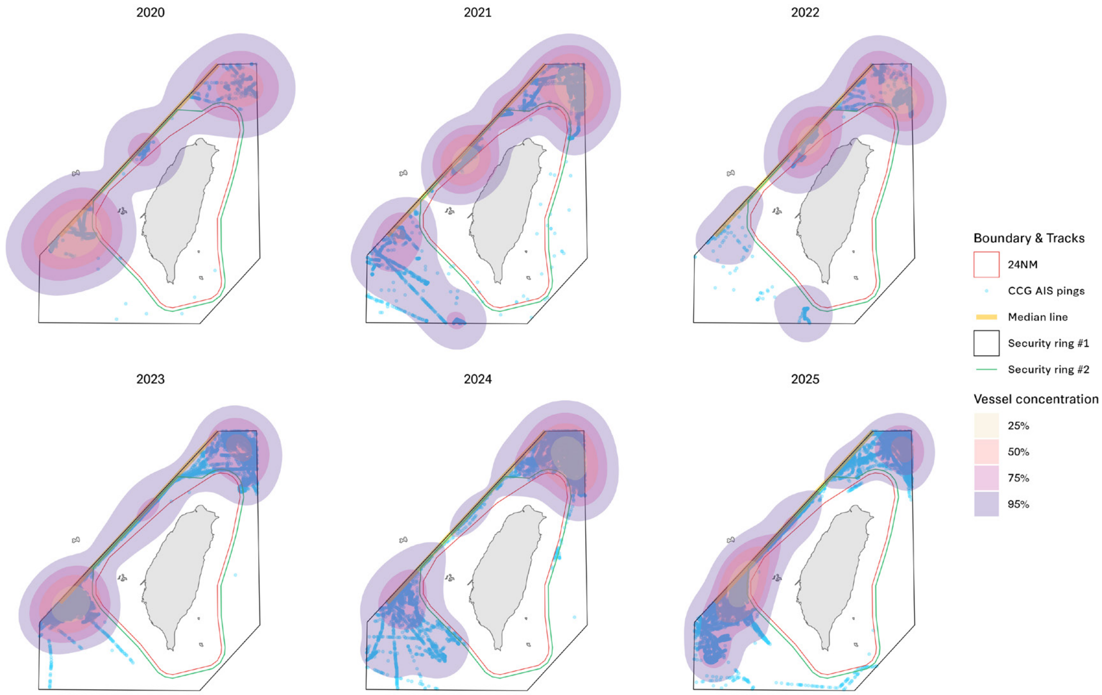
The data from the second security ring is even more alarming, as entering the second ring indicates deeper and more sustained penetration. The second security ring closes the distance to the 24NM contiguous zone boundary to five nautical miles, with the exception of the median line zone. The increase in the average number of ships entering this second ring increased by over 130 percent from 2024 (0.082) to 2025 (0.195). It is rare for the CCG to push past the 24NM contiguous zone boundary, registering nearly zero distinct ships each year, with no ships actually penetrating the 24NM contiguous zone boundary in 2024.

Table 1: Average Daily Number of Distinct Ships in Taiwan's Security Rings and 24NM Contiguous Zone Boundary, 2020–2025

Year	Security Ring #1	Security Ring #2	24NM Boundary
2020	0.151	0.038	0.00548
2021	0.507	0.162	0.04380
2022	0.184	0.303	0.00548
2023	0.679	0.107	0.00274
2024	0.675	0.082	0
2025	0.956	0.195	0.0137

Source: Author analysis of AIS data from General Atomics Optix.

Figure 5: Geographic Density of CCG Within Taiwan's Security Rings, 2020–2025



Source: Author analysis of AIS data from General Atomics Optix, security rings one and two, Taiwan's 24NM contiguous zone boundary.

Figure 5 presents kernel density estimations (KDE) and shows the concentration of hotspots by the CCG over five years (2020-2025). Three zones consistently exhibit the highest density each year, as denoted by the 25 percent concentration of the KDE: southwest, northeast, and the median line. In conjunction with Table 2, Figure 5 reveals that in 2020, the most active zone was the median line zone where almost every two days a CCG vessel would penetrate, followed by the northeastern and southwestern zones where a vessel would enter about every three days. Compared to 2020, in 2025, the averages increased in three out of five zones. In the median zone, a distinct CCG vessel entered almost every day (up 47 percent from 2020), in the northeast, a vessel entered about every 1.5 days (up about 35 percent), and in the southwest, a vessel entered about every 2.3 days (a modest 19 percent increase).

The data in Table 2 reveals that over time, there has been a sustained increased in CCG incursions into the median, northeastern, and southwestern zones that coincides with the PRC's pressure campaign. Responding to this increased pressure draws more resources from Taiwan. Analysis, however, should be done with caution. The presence of CCG ships should be considered in relation to the vessels' distances from the innermost boundary, the 24NM contiguous zone boundary. The closer a ship travels to the 24NM contiguous zone boundary, the more likely Taiwan is to use resources and deny or expel CCG entry if penetrated. As such, distance traveled can also serve as a method to measure pressure intensity, in addition to presence.

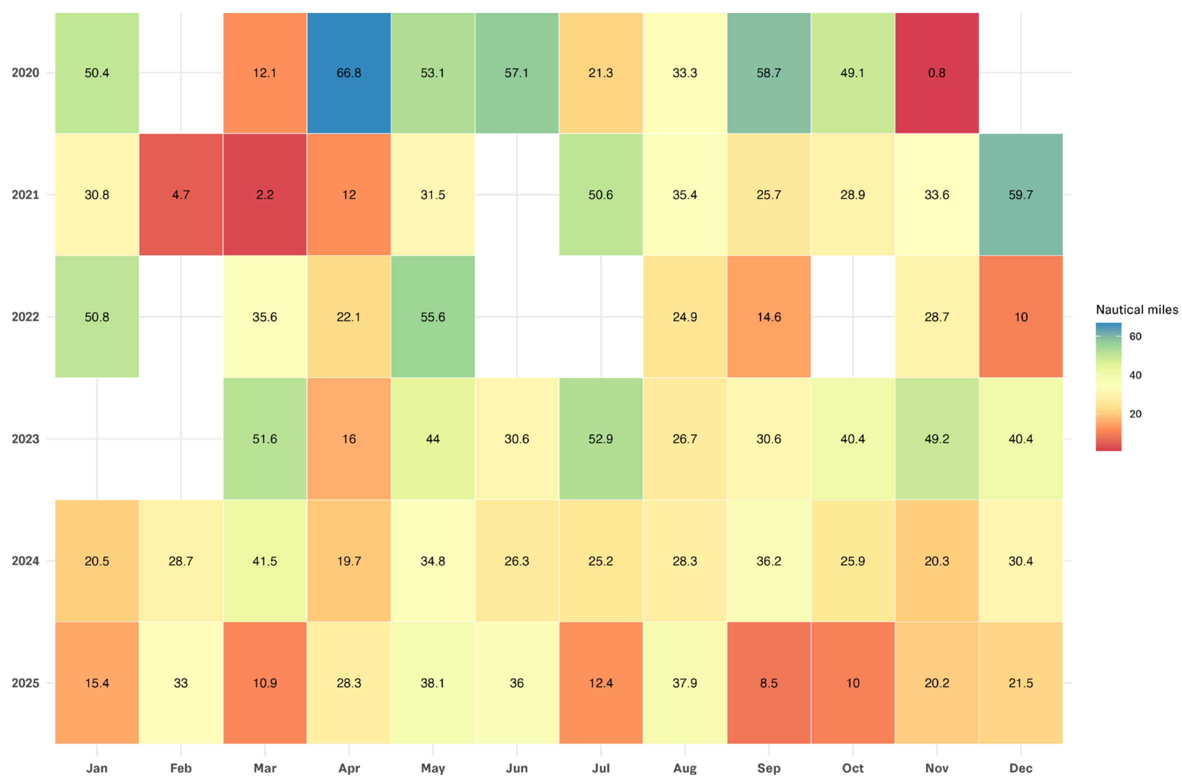
Table 2: Average Number of Distinct CCG Ships in Taiwan's Security Zones, 2020–2025

Year	Median	Northeastern	Eastern	Southern	Southwestern
2020	0.595	0.452	0.0238	0.0476	0.357
2021	0.752	0.431	0.176	0.0784	0.520
2022	0.574	0.556	—	—	0.296
2023	0.950	0.617	0.0284	—	0.695
2024	0.690	0.744	0.0893	—	0.214
2025	0.876	0.614	0.0149	0.0198	0.426

Note: "—" denotes no AIS data captured, collected or detected for the zone. The original data size is subject to the parameters the teams subsets for in Optix, there may be more vessels in the zones without AIS signatures.

Source: Author analysis of AIS data from General Atomics Optix.

Figure 6: Median Monthly Distance Traveled to Taiwan's 24NM by CCG Vessels, 2020–2025

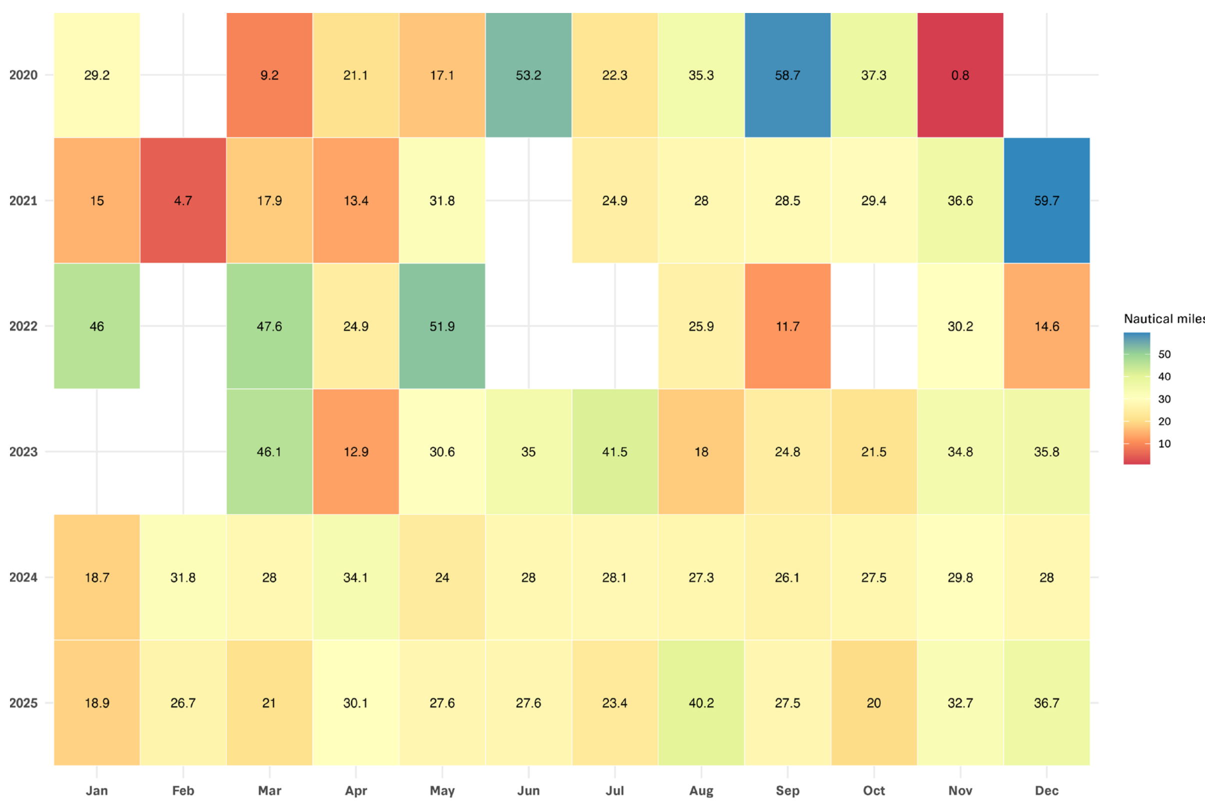


Source: Author's nearest distance analysis of AIS data from General Atomics Intelligence Optix to Taiwan's 24NM contiguous zone boundary. The distance was converted to nautical miles units before calculating the median by month and year.

Figure 6 provides details on the depth of penetration and reveals the degrees of pressure as measured by the daily median distance traveled by CCG vessels toward the 24NM contiguous zone boundary. Because the distribution of the data skewed slightly right when considered in aggregate (see Appendix), the research team opted to use the median distances for its analysis in Figure 6. Lower nautical mile values mean deeper penetration and closer encounters with the 24NM contiguous boundary. When this occurs, the probability of breaching the 24NM contiguous zone boundary increases, as does the likelihood Taiwan must dispatch resources to respond and deny CCG entry. As seen in Figure 6, the median distances traveled have decreased since 2020, with the median distance traveled toward Taiwan's 24NM contiguous zone boundary hitting a low of 8.5 nautical miles in September 2025. In addition, in 2025, more ships got closer to the 24NM than in previous years. Specifically, 5 out of 12 months in 2025 experienced lower distances: September (8.5 nautical miles), October (10 nautical miles), March (10.9 nautical miles), July (12.4 nautical miles) and January (15.4 nautical miles).

Figure 7 displays the average minimum distance traveled each day per vessel. A comparison of the data in Figure 6 (median distance traveled) with that in Figure 7 (average minimum distance traveled) reveals that the minimum distance traveled per ship each day does not decrease at the same rate (or to the same level) as the aggregate. Rather, the lowest average minimum distance traveled in 2025 was in January (18.9 nautical miles) followed by October (20 nautical miles), March (21 nautical miles), July (23.4 nautical miles), and February (26.7 nautical miles). Analyzing the minimum distance travel to the 24 NM border shows that while the CCG continues to close in on the 24NM contiguous zone boundary, its vessels are traveling shorter distances in 2025 than in previous years, though the 2025 aggregate is much smaller in relation to earlier aggregates.

Figure 7: Average Monthly Minimum Distance Traveled to 24NM by CCG Vessels, 2020–2025



Source: Author's nearest distance analysis of AIS data from General Atomics Intelligence Optix to Taiwan's 24NM contiguous zone boundary. The distance was converted to nautical miles units before calculating the daily minimum distance and averaging by month and year.

Data collected from AIS and MMSI numbers supports the claim that the CCP is pursuing a sustained campaign of pressure by sea. Both the increase in CCG activity within the security space following President Tsai's visit to the United States and the increasing proximity of CCG vessels to the 24NM contiguous zone boundary indicate intensifying pressure on Taiwan from the PRC. The sea-based pressure campaign comprising the PLAN's power projection (e.g., Joint Sword exercises) and the CCG activities in and around Taiwan's security zones and rings is reinforced by aircraft supporting the PLAN.[52] It is to the air domain that this analysis now turns.

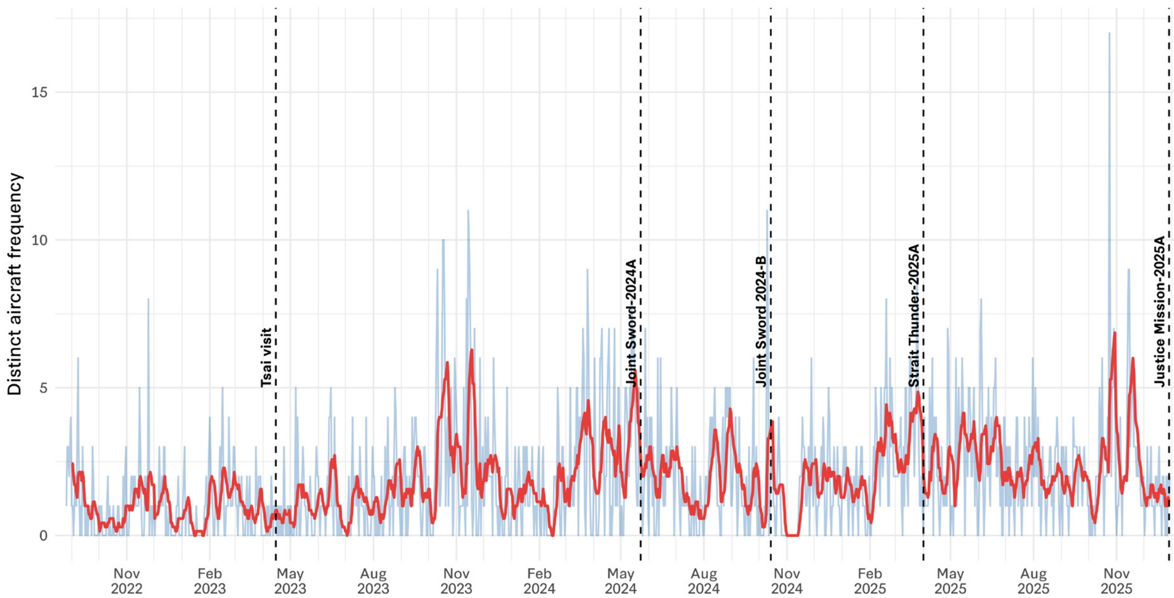
Findings

Air Domain

As the PLA has increased its pressure campaign on the water, the publicly available ADS-B transponder data indicates that the PLA's aerial arm—the PLA Air Force—has enacted a sustained and growing pressure campaign on Taiwan since at least 2022.

This study uses the transponder signatures from aircraft that likely carry not only PLAAF supplies and personnel, but in the case of UAVs, the mission sets near Taiwan. While the publicly available signatures exported from Aireon do not include PLA military aircraft such as fighter jets and bombers—which often use encrypted transponders or signature control—this study argues that the captured ADS-B air traffic data provides a proxy for exercise and mission sets and shows how Beijing applies pressure in and through the air domain.[53] Therefore, the study pushes past ADIZ violations, which are commonly used in strategic analysis of PRC pressure on Taiwan, and analyzes a subset of air signatures from the PLAAF.[54]

Figure 8: Seven-Day Rolling Average of Distinct PLA Aircraft Traffic, 2022–2025



Source: Author's point-in-polygon analysis of open-source reported military aircraft using Aireon ADS-B Mode S data from General Atomics Intelligence Optix near (4 kilometer buffer) or in OSM PLA airfields/military bases/dual use airports.

Figure 8 presents the rolling seven-day average of publicly reported military aircraft at select dual use airfields/airports likely under the PRC's central, east, and southern commands from August 2022 to December 2025.[55] The air traffic data comprises a subset of transport, attack, and UAV aircraft owned by the PLA Army, Airforce, and Aviation Industry Corporation traveling to identified PRC airstrips and airports.[56] Figure 8 highlights a sustained and growing trend of activity since 2022. From 2022 to 2025, there were 102 distinct aircraft found to be traveling near or directly to openly sourced and mapped PRC military airfields and airports in central, eastern, and southern China that may facilitate operations near Taiwan.[57]

Table 3 contains the average number of GPS pings from ADS-B data picked up by receivers for each distinct aircraft. The increase over four years is notable, going from 36 distinct aircraft in 2022, with an average of 194 pings per aircraft, to 78 distinct aircraft by December 2025, with over 2,000 average pings per aircraft. This represents an increase both in the number of aircraft traveling to military bases as well as an increase in ping activity. What is unknown is the frequency of flights or mission sets that target Taiwan specifically rather than missions in the South China Sea or ones targeting Japan. The expansion of tensions into different areas of the South China Sea and the Pacific could be responsible for the increased pings per aircraft, or some other mechanical feature of the aircraft may be resulting in increased pings.

Building on the increased pings by known military aircraft, Table 4 lists the five most active, or most frequently detected, model and class of aircraft in the team's data subset. Table 4 reveals that the Wing Loong-10—a type of UAV—is the type of aircraft most frequently picked up by the ADS-B.[58]

Table 3: Data Cumulation by Distinct Military Aircraft, 2022–2025

Year	Ping Cumulation	Distinct Aircraft	Average Record
2022	6,978	36	194
2023	57,411	71	809
2024	174,794	76	2,300
2025	189,267	78	2,426

Source: Authors analysis of ADS-B data from General Atomics Intelligence Optix via Aireon.

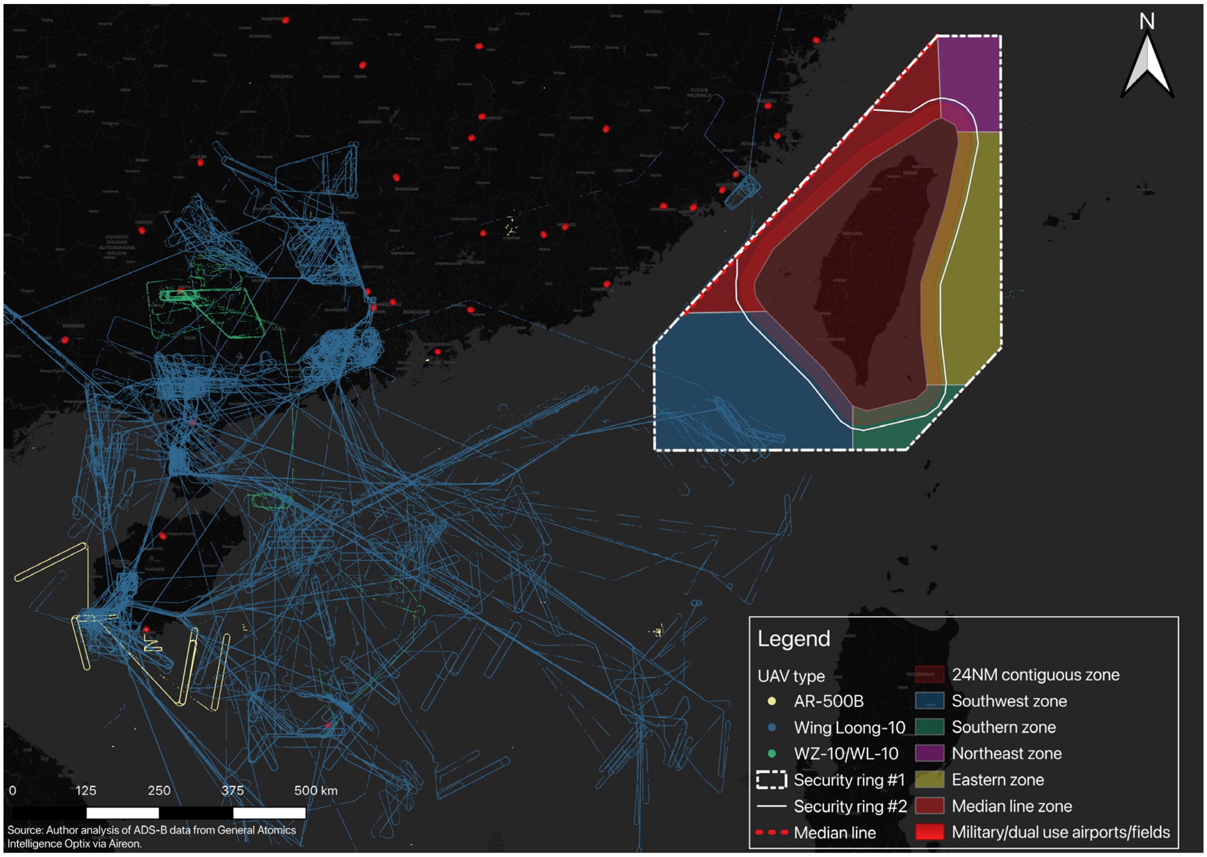
To demonstrate some of the missions by UAVs, select activities from January 2024 to December 2025 are unpacked further in Figure 9. As the figure displays, most UAV flights take off from the Chinese provinces of Hainan and Guandong and carry out mission sets in the South China Sea. However, there are recorded instances of UAVs sporadically entering Taiwan's ADIZ or flying parallel to it. This indicates that the priority deployment of UAV assets within the study's data subset is for mission sets within the South China Sea and not directed at Taiwan. There may be more UAV use near Taiwan that has not been captured, as data from open-source tail watching is limited. However, given the multi-area use of the UAVs, it is a fair assumption that the aircraft are being used to apply pressure on Taiwan via ISR missions that likely support sea domain operations and intelligence preparation of the battlefield.

Table 4: Five Most Active Aircraft Types, 2022–2025

Ping Cumulation	Aircraft Type	Aircraft Class
219,953	Wing Loong-10	UAV
94,118	Z-10	Attack Helicopter
47,415	Z-10 A	Attack Helicopter
18,083	AR-500B	UAV
6,886	A319 115	Transport
2,566	CRJ 200LR	Transport

Source: Authors analysis of ADS-B data from General Atomics Intelligence Optix via Aireon.

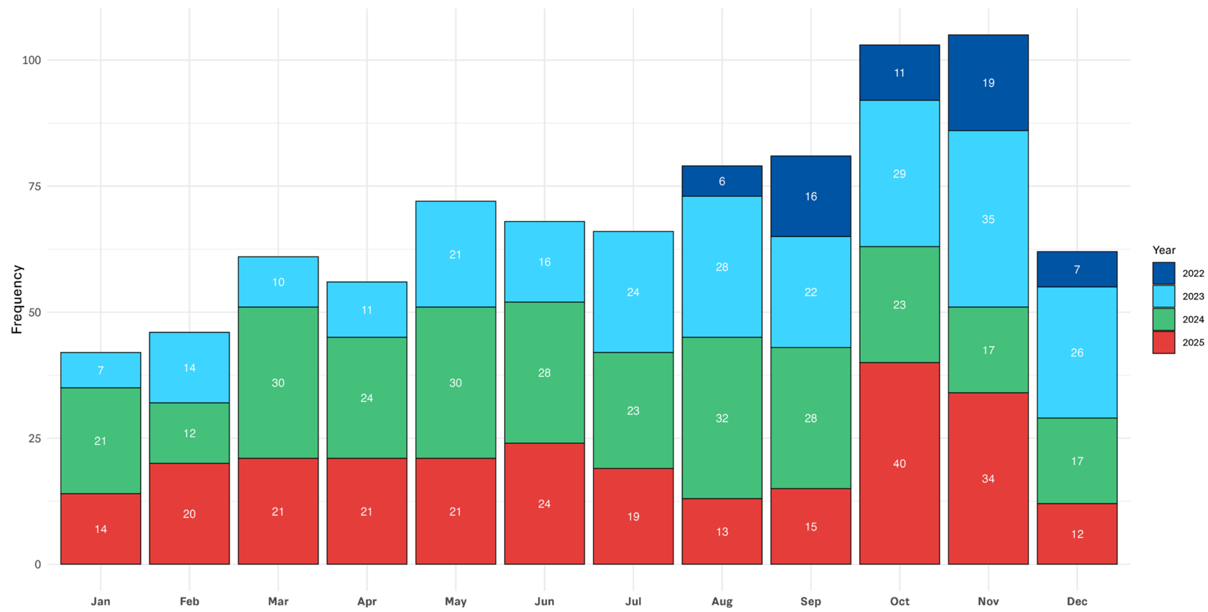
Figure 9: Select UAV Movement in the South China Sea and near Taiwan, 2024–2025



Source: Author analysis of ADS-B data from General Atomics Intelligence Optix via Aireon.

Figure 10 breaks down the distinct number of aircraft visiting dual use airfields/airports by month; that is, every distinct military plane (as tracked by their Mode S Addresses) was counted for each given month. The data shows that from August 2022 to December 2025, October (103) and November (105) are the months that cumulatively witness the highest levels of air traffic over time.

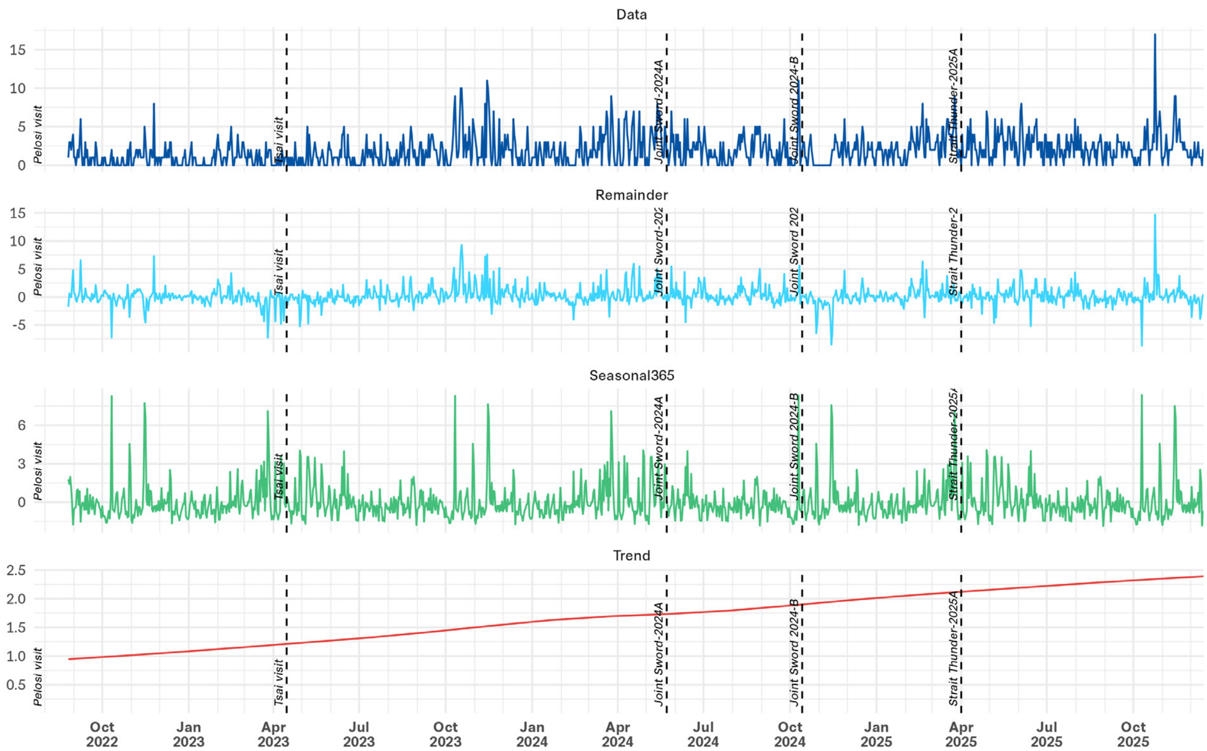
Figure 10: Monthly Distinct Plane Visits near or Directly to Dual Use Airfields and Airports, August 2022–December 2025



Source: Author's point-in-polygon analysis of open-source reported military aircraft using Aireon ADS-B Mode S data from General Atomics Intelligence Optix near (4 kilometer buffer) or in OSM PLA airfields.

The nature of PLA air traffic is cyclical—similar to CCG vessels at sea—as revealed in Figure 11, which contains the de-seasoned military air traffic data. This image shows a sustained and increasing air traffic trend throughout the eastern Chinese dual use military airfields and airports following the Joint Sword-2024A exercise in May 2024 and continuing to increase after the Joint Sword-2024B (October 2024), Strait Thunder-2025A (April 2025) exercises into the end of the year with Justice Mission-2025A (December 2025).

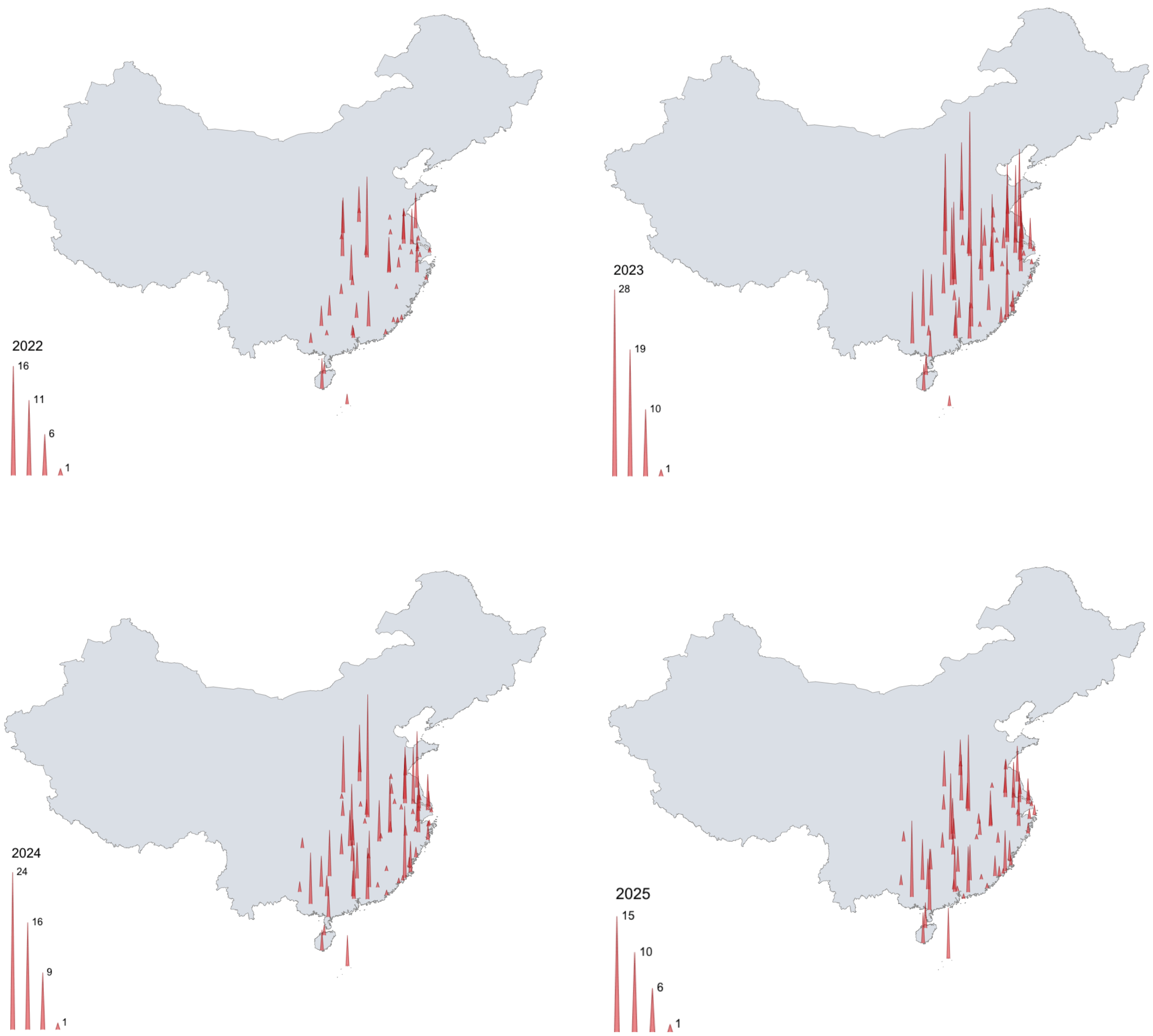
Figure 11: De-Seasoned Air Traffic, August 2022–December 2025



Source: Author's point-in-polygon analysis of open-source reported military aircraft using Aireon ADS-B Mode S data near (4 kilometer buffer) or in OSM PLA airfields. The MSTL calculates the lowest root mean square error for a trend cycle, and year windows were used for a balance between overfit and seasonality. See Bandara, Hyndman, and Bergmeir, "MSTL: A Seasonal-Trend Decomposition Algorithm."

Figure 12 illustrates the geographic spread of aircraft visits, highlighting the traffic by airfield and base. The images reveals a stark increase in 2023 activity compared to 2022, an increase which was sustained in 2024 and 2025. Figure 12 exposes two other notable trends: (1) a concentration of visits by distinct aircraft flying out of the Hainan Province and (2) an increase in visits to Woody Island (Yongxing).

Figure 12: Yearly Airfield Activity by Distinct Aircraft, August 2022–December 2025

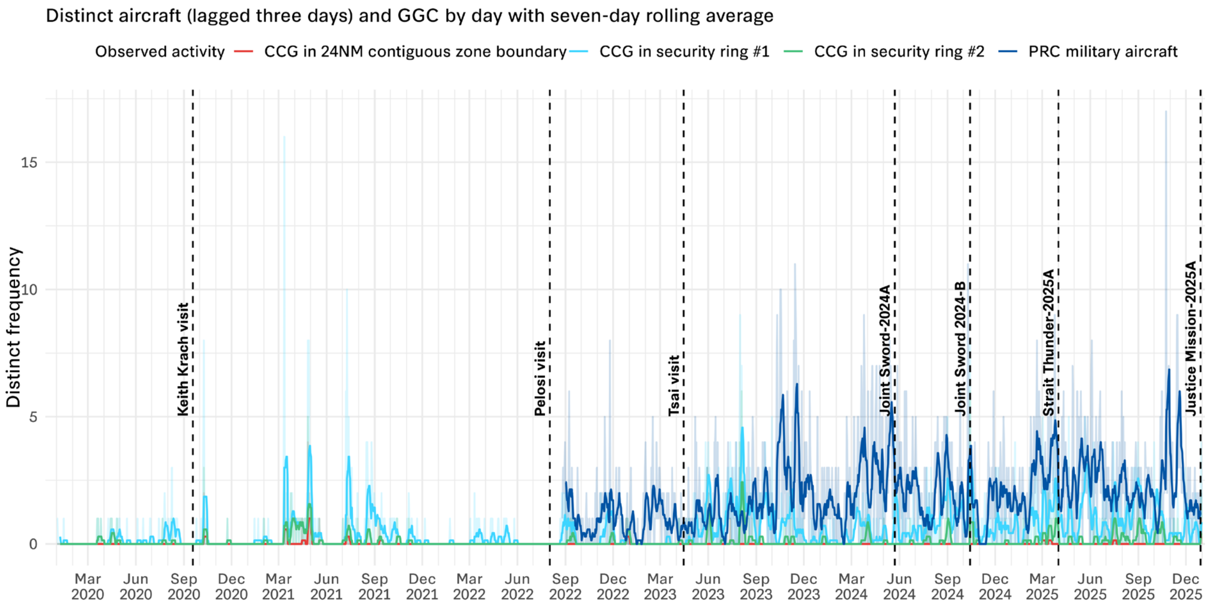


Source: Author analysis of ADS-B data from General Atomics Intelligence Optix via Aireon.

Integrated Pressure Patterns

Combining activities in both domains into a single focus reveals the PRC's combined sea and air pressure campaign against Taiwan. The research team lagged the distinct military air traffic by three days under the assumption that the PLAAF, PLAN, and CCG take approximately three days to execute planning. The result is a combined plot (see Figure 13), which accounts for both sea and air activities facilitating the PRC pressure campaign on Taiwan.

Figure 13: Pressure Trends in Sea and Air, 2020–2025



Source: Author's point-in-polygon analysis of open-source reported military aircraft using Aireon ADS-B Mode S data from General Atomics Intelligence Optix near (4-kilometer buffer) or in OSM PLA airfields. In addition, PiP analysis of AIS data from General Atomics Optix, Taiwan's security rings one and two, and 24NM contiguous zone boundary. The daily distinct aircraft data is lagged by three days, reflecting time to prepare for an exercise after material and personal arrival. CCG vessels are not lagged.

Figure 14: Integrated Pressure Index, 2025

Source: Author's analysis of AIS and ADS-B. For the index formula, please see the appendix.

As expected, based on the joint analyses of sea and air-domain activities, increased pressure activity occurred and was sustained following Speaker Pelosi's August 2022 visit to Taiwan and President Tsai's March/April 2023 visit to the United States.

To systematically capture the intensity of daily PRC maritime and air activity near Taiwan, the researchers constructed an IPI for the year 2025 (Figure 14). This index combines several of the observable indicators of maritime behavior analyzed in this study, including the presence and time loitering by CCG vessels operating near Taiwan's maritime boundaries, the occurrence of maritime drills, and the lagged amount of PLA aircraft detected. Each element is weighted according to expert input. (see the Appendix for further details). The index also incorporates a measure of proximity pressure derived from the minimum daily distance traveled by CCG vessels toward Taiwan. The resulting IPI is rescaled to 0-100 to allow for intuitive interpretation over time, similar to a temperature gauge. This approach enables a standardized daily measure of PRC maritime and air pressure, facilitating comparisons across periods and the evaluation of responses to political events or coordinated military activities.

Recommendations

Under the leadership of President Xi Jinping, the CCP has shifted from occasional military signaling to a normalized, high-tempo strategy of coercive pressure. As this analysis demonstrates, PLA activity is not merely a series of isolated incidents but rather a long-term sustained campaign designed to erode Taiwan's defensive buffer zones and exhaust its military readiness. By quantifying this pressure through a three-ring maritime security framework, one can see that incursions into Taiwan's second maritime security ring have more than quadrupled, and CCG activity has increased fivefold since 2020.

PRC "slow drip" coercion aims to achieve reunification by exploiting gaps in international norms, staying below the threshold of open conflict while simultaneously wearing down Taiwan's assets and the political will of its partners. To retain a competitive advantage, the United States must move beyond reactive signaling and provide direct support, in addition to weapon systems. Washington needs an interagency "menu" of options that treats this pressure as a standing campaign to counter rather than as a series of ad hoc crises to which it has to react.

The following recommendations provide a roadmap for institutionalizing the study's IPI to shift the burden away from high-end U.S. and Taiwan assets and back onto the PRC. By leveraging existing authorities—such as Chapter 10, Section 333 of the U.S. Code and Contractor-Owned, Contractor-Operated (COCO) or commercial solutions—the options presented here are designed to turn Beijing's gray zone tactics into a predictable strategic liability.

1. **Stand up a coalition-based Taiwan Pressure Observatory and fund it as a campaigning capability.**

This report demonstrates the value of turning diffuse gray zone activity into measurable, comparable indicators (e.g., the IPI), arguing that empirically grounded baselines help tailor denial strategies and that the best way to confront slow pressure is to document it and mobilize resources to undermine it.

The U.S. executive branch should treat that insight as an operational requirement: If Beijing's center of gravity is "pressure without escalation," then persistent attribution and shared situational awareness become the foundation for every other policy tool.

The National Security Council should direct the Department of War—likely through Office of the Secretary of War for Policy and USINDOPACOM J2/J3—and the Department of State to coordinate and establish a standing Taiwan Pressure Observatory. This small fusion cell would produce: (1) a weekly interactive pressure dashboard (IPI-style), (2) a public monthly trends product for allied messaging, and (3) a "trigger memo" that links observable thresholds (e.g., second-ring penetrations, cable cuts, and abnormal airfield surges) to preapproved response options discussed further in recommendation three below. The cell should explicitly build on what this report already uses—commercial and open-source feeds (AIS, ADS-B, and commercial tooling)—but also expand beyond ADS-B limitations with passive radio frequency and other sensing. This is because, as the report notes, its air dataset only captures aircraft that keep ADS-B on and does not include fighter or bomber activity. The defense ministries of Taiwan and Japan provide similar daily reporting of activity, including zone flyover, but do not publish data that the public, academia, or research institutes can repurpose for longer-term study and analysis.[59]

Resourcing should come from three mutually reinforcing channels that the executive can operationalize immediately:

1. Increase maritime domain intelligence/awareness funding inside the Pacific Deterrence Initiative by carving out a dedicated line for "Taiwan Pressure Monitoring and Attribution" for commercial data buys, cloud analytics, and partner data sharing. The Congressional Research Service (CRS) reports the Pacific Deterrence Initiative's fiscal year 2025 request at $9.86 billion, including $1.11 billion requested for "maritime security [and] maritime domain awareness operations," creating a realistic budget wedge for a dedicated pressure-monitoring tranche without inventing a new appropriation account.[60] The FY 2026 level is $10 billion, providing a ready source of funding.[61]
2. Expand and target Chapter 10, Section 333 of the U.S. Code ("train and equip") packages specifically at pressure-monitoring capabilities linked to maritime security, military intelligence, and air domain awareness, which are already explicitly within the statute. This effort will require deeper Departments of War and State planning that can be integrated with the fusion cell discussed above.[62]
3. Enable pooled democratic funding by using Chapter 10, Section 2608 of the U.S. Code, which authorizes the Department of War to accept foreign contributions and retain them in a Defense Cooperation Account (implementable via MOUs/agreements).[63] This mechanism would allow for deeper burden sharing and provide a means for Australia, Japan, and other

democracies to co-fund a shared maritime domain intelligence/awareness capability without seeking new congressional authorities.

The Observatory should be coalition by design: Australia, Japan, and the Philippines should embed liaison analysts and contribute data and data-collection coverage while commercial partners provide scalable feeds and tooling. This report's own approach is already anchored in commercially available platforms and AIS/ADS-B sources. The recommended policy adjustment is to make that model persistent and shared rather than episodic and U.S.-only. If allies and partners could contribute $100 million, it would reduce the burden on U.S. defense budgets and support a rapid rollout of the fusion cell. This rollout would see broad data purchases and could extend to commercial ISR flights as needed to cover gaps while also funding orders for military personnel to staff the center.

2. **Create a Taiwan Readiness Relief Package fast lane to reduce scramble costs and shift the tracking burden onto Taiwan capacity.**

This report's data shows that Beijing is increasing the frequency and depth of its coercive activity in order to impose cumulative operational costs, not just signal intent. In response, the U.S. competitive objective should be to make Taiwan's day-to-day detection, tracking, and endurance cheaper and more sustainable so PRC incursions do not force constant U.S. (or Taiwan) readiness burn.

The U.S. State Department Bureau of Political and Military Affairs and the Department of War's Defense Security Cooperation Agency should stand up a small "Taiwan Fast Lane" cell that does three things differently from business-as-usual:

1. bundles key ISR/endurance cases into a small number of executable efforts that reduce paperwork and bureaucratic friction;
2. uses the Taiwan Enhanced Resilience Act–enabled Presidential Drawdown Authority (PDA) to bridge the most acute readiness gaps (i.e., spares, ISR enablers, and command and control hardware) while Foreign Military Sales (FMS) deliveries move; and
3. applies Foreign Military Financing (FMF) and the Taiwan Security Cooperation Initiative as financing tools to move from "approved sales" to "fielded capability," focusing on sustainment and training pipelines, not just procurement.[64]

These efforts could build on existing reforms to either FMS or FMF. CRS notes that from 2015–2025, the executive branch notified Congress of over $28 billion in FMS to Taiwan, and that Congress created new mechanisms such as the PDA and FMF authorization for Taiwan because of long delivery timelines. CRS also notes three PDA packages totaling $1.5 billion since the Taiwan Enhanced Resilience Act 's enactment and describes the Taiwan Security Cooperation Initiative's funding levels under consideration.[65]

Furthermore, this effort should prioritize systems that directly reduce the need for constant, expensive close tracking by U.S. assets. Priority systems should include:

- E-2D Advanced Hawkeye (AHE, or a functionally equivalent airborne early warning upgrade path) to improve wide-area detection and cueing against air and maritime activity and mitigate the issue of Taiwan's current aging E-2K fleet. Based on Japan's recent purchase of AHE, the cost would likely be $1.381 billion for five aircraft.[66]
- Aerial refueling capacity (organic or contracted) to increase Taiwan's airborne endurance and reduce reliance on U.S. tankers during routine surges. Of note, this capability can be accessed flexibly through COCO solutions to reduce the estimated cost ($500 million for two KC-46, based on Israel's recent purchase request).[67]
- Data links, ground-based sensors, spares, and sustainment that convert new platforms into reliable daily operations.
- Space-based sensor services to enhance redundancy, resiliency, and fidelity of ISR capabilities and capacities.

Japan and other close partners can support training pipelines, provide maintenance partnerships, and co-fund enabling infrastructure through the pooled mechanisms outlined in recommendation one above. The point is not more U.S. sorties, but rather a Taiwan-centered monitoring and endurance architecture that makes PRC pressure less efficient.

3. **Build an IPI-triggered pressure response ladder so measurement drives consequences.**

Beijing's advantage in a pressure campaign is that each increment is ambiguous enough to argue away, but frequent enough to normalize. This report's emphasis on building empirical baselines and documenting slow campaigns implies the next step: pre-committing to responses so coercion has predictable political and economic costs.

The National Security Council should direct an interagency process (e.g., State, Department of War, Treasury, or the intelligence community) to codify a ladder tied to Observatory metrics as outlined in recommendation one. The ladder should link concrete observable behaviors (e.g., sustained second-ring penetrations, CCG ramming/boarding, coordinated cable-cutting patterns, and airfield surges) to actions that can be executed quickly, including

- **information:** rapid declassification/attribution packages backed by time-series IPI visuals; coordinated allied messaging;
- **diplomacy:** joint demarches and public statements with the European Union, the G7, and Japan; tailored diplomatic consequences for repeat offenders;
- **financial/legal:** pre-drafted sanctions and visa restrictions against entities and individuals supporting coercion; maritime insurance and port-state scrutiny against implicated vessels where legally supportable; and
- **security assistance accelerants:** automatic release of pre-positioned sustainment or spares security packages or drawdown packages when thresholds are crossed (to deny Beijing the "wear down" objective).

Developing this process will likely require augmenting aspects of the existing Strategic Planning Framework and other parallel executive agency constructs to build a robust menu of flexible deterrent and response options that have been pre-screened and preapproved.[68] This in turn implies a need for congressional engagement and oversight. This approach will achieve outsized effects if Japan and other democracies agree (even if only privately at first) on threshold-based actions so that Beijing cannot pick off responders one by one. Furthermore, the cost could be bundled into the Observatory Fusion Cell to reduce the bureaucratic friction required to set up the interagency process.

Conclusion

Countering Authoritarian Pressure Campaigns

The data from January 2020 to December 2025 reveals a clear and concerning trajectory: Beijing's pressure strategy against Taiwan is no longer a series of episodic events, but rather a systematic campaign of attrition. By increasing the frequency of CCG incursions into Taiwan's near waters by over 500 percent and increasing penetrations into the second security ring, Beijing is attempting to normalize its assertive behavior and exhaust Taipei's defensive capacity. This slow-drip coercion, supported by a sustained increase in PLA military aircraft activity at strategic airfields/airports, seeks to fundamentally alter the status quo without crossing the threshold of kinetic war.

The implementation of the IPI and the proposed interagency recommendations provide a framework to flip the script on Beijing's wear-down strategy. By institutionalizing data-driven monitoring and leveraging authorities like Chapter 10, Section 333 of the U.S. Code and commercial contracts, the United States and its allies can achieve the following:

- **Reduce the "pressure tax."** Shifting the burden of persistence from high-cost military assets to commercial sensing and contractor-operated refueling allows Taiwan and the United States to preserve high-end readiness for actual crises.
- **Eliminate ambiguity.** Using unclassified, evidence-based reporting through the IPI turns the PRC's "law enforcement" narrative into a documented record of regional instability that suppresses and erodes CCP hybrid warfare efforts in the information domain.

- **Strengthen allied persistence.** Creating a "Persistence Accelerator" ensures that Taiwan has the airborne early warning, refueling, and sustainment capacities to stay in the fight longer and more efficiently.

As Taiwan remains a strategic node in the first island chain and a bellwether for regional democracy, the cost of inaction–allowing the CCP to successfully normalize its encroachment–is too high. Moving toward a proactive, persistence-based strategy ensures that the Washington and its partners do not just observe Beijing's pressure, but instead systematically undermine its efficacy.

About the Authors

Jose M. Macias is an associate data fellow in the Futures Lab within the Defense and Security Department at the Center for Strategic and International Studies (CSIS). He works as a data scientist on quantitative international relations research projects that cover great power competition. Jose has experience creating algorithms to quantify gray zone activities using big data. He has experience with data wrangling, cleaning, visualization, and modeling using regression techniques (OLS, DiD, RDD), machine learning (LDA, LASSO, DBSCAN), geospatial analysis (kernel density estimations, shortest-distance analyses, point value extraction). Additionally, he was a fellow with the Congressional Hispanic Caucus Institute, serving under U.S. Senator Angus S. King's defense team and managing the cybersecurity portfolio. Jose holds a Master of Public Policy (MPP) from the University of Chicago's Harris School of Public Policy, with a concentration in data analytics. As a first-generation student, he earned an associate of arts degree in political science from Fullerton College and a dual BA in political science and international relations from the University of California, Davis.

Benjamin Jensen is director of the Futures Lab and a senior fellow for the Defense and Security Department at the CSIS. At CSIS, Dr. Jensen leads research initiatives on applying data science and AI and machine learning to study the changing character of war and statecraft. Under his leadership, Futures Lab has pioneered building AI applications into wargames and innovative scenario exercises. The exercise topics range from major war, competitive strategy, and national mobilization to economic security, energy politics, and national resilience. He is also the Frank E. Petersen Chair for Emerging Technology and a professor of strategic studies at the Marine Corps University School of Advanced Warfighting (MCU). At MCU, he leads a research program on future war and teaches seminars on modern operational art and joint-all domain operations. Dr. Jensen has authored five books including *Information at War: Military Innovation, Battle Networks, and the Future of Artificial Intelligence* (Georgetown University Press, 2022), *Military Strategy in the 21st Century: People, Connectivity, and Competition* (Cambria, 2018), *Cyber Strategy: The Evolving Character of Power and Coercion* (Oxford University Press, 2018), and *Forging the Sword: Doctrinal Change in the U.S. Army* (Stanford University Press 2016). He also served as senior research director for the U.S. Cyberspace Solarium Commission and is a reserve officer in the U.S. Army, with command experience from platoon to battalion. Dr. Jensen graduated from the University of Wisconsin-Madison and earned his MA and PhD from the American University School of International Service.

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Appendix

Time-Series AIS Extraction

The research team constructed the initial AIS data frame by using the security ring shapefile in Optix. The team ran queries to capture any Chinese-flagged law enforcement or military vessels found within the defined space. The next step was to systematically clean and check the accuracy of the AIS data. In doing so, the team found classification discrepancies in the AIS data stream. Upon close review, the team identified several fishing ships mistakenly labeled as law enforcement. The initial check highlighted that while these classified vessels were docking within Taiwan's ports, following a review of their patterns of life and names, the research team deemed these instances as rare classification mistakes. The results for vessels labeled as military from the PLAN proved to be less reliable due to variable MMSI numbers and inconsistencies related to reported sightings of vessels near Taiwan. Moreover, there is debate in the policy realm as to whether PLAN vessels would actually openly broadcast AIS signatures. After much consideration, the team opted not to include vessels labeled as military ships at this time due to these data validity concerns and instead focused on CCG vessels.

Construction of Space and Security Rings

After completing the extraction of AIS data and constructing the AIS data frame, researchers designed the security rings as a shapefile in the open-source software QGIS. As a starting point, researchers partially used the ADIZ of Taiwan to symbolize the first security ring. To aid in identifying zones of pressure and penetration, the team used the same area groupings published by the CSIS China Power Project in a March 2023 publication by Ben Lewis.[69] These areas are northeastern, eastern, southern, southwestern, and the median line. At that point, Tao-Hung Chang, a ROC naval officer and visiting fellow with the China Power Project, directly participated with the design, using his expertise to focus on the pattern of life of CCG AIS data and Taiwan maritime policy. This led to the demarcation of a second security ring starting on the north of the island with the median line and extending approximately 33 nautical miles east before circulating 5 nautical miles from the 24NM contiguous zone boundary and extending approximately 15 nautical miles from the south to the median line as defined by the CCG AIS pattern of life. The final security ring is the hard 24NM contiguous zone boundary, which Taiwan actively protects.

The collaboration with Tao-Hung represents the bridging of military practice with academia and the Futures Lab is grateful for his time, attention, and innovative ideas, and thanks the CSIS China Power Project for supporting his cross-department collaboration.

Distance Calculations

The next step was to operationalize the security rings and the AIS data frame by calculating the nearest distance from each AIS point (longitude and latitude) to the second and third security rings. This was carried out in the R programming language using the simple features (sf) and tidyverse libraries. The AIS data frame was converted to point geometry and reprojected to coordinate reference system EPSG:3826; the security ring shapefile was also reprojected to EPSG:3826.

The researchers then used the function st_distance() to calculate nearest distance and then converted the values to nautical miles (NM). This data laid the foundation for Figures 6 and 7 where the team calculated median and minimum average distances, respectively. Minimum average distances represent the closet distance a distinct CCG vessel traveled to Taiwan's 24NM contiguous zone boundary on a given day and was calculated using a group_by() function on each day of a year and distinct MMSI numbers followed by min(). These values are also used to construct the IPI.

Point in Polygon and Kernal Density Estimation

To analyze the geospatial tracking of CCG movement over time, the research team leveraged the AIS data for a point-in-polygon (PiP) analysis. This PiP extracted and spatially joined the attributes from the security ring shapefile into the AIS data frame as additional columns. In this manner, the team was able to tabulate frequency and description statistics by zone.

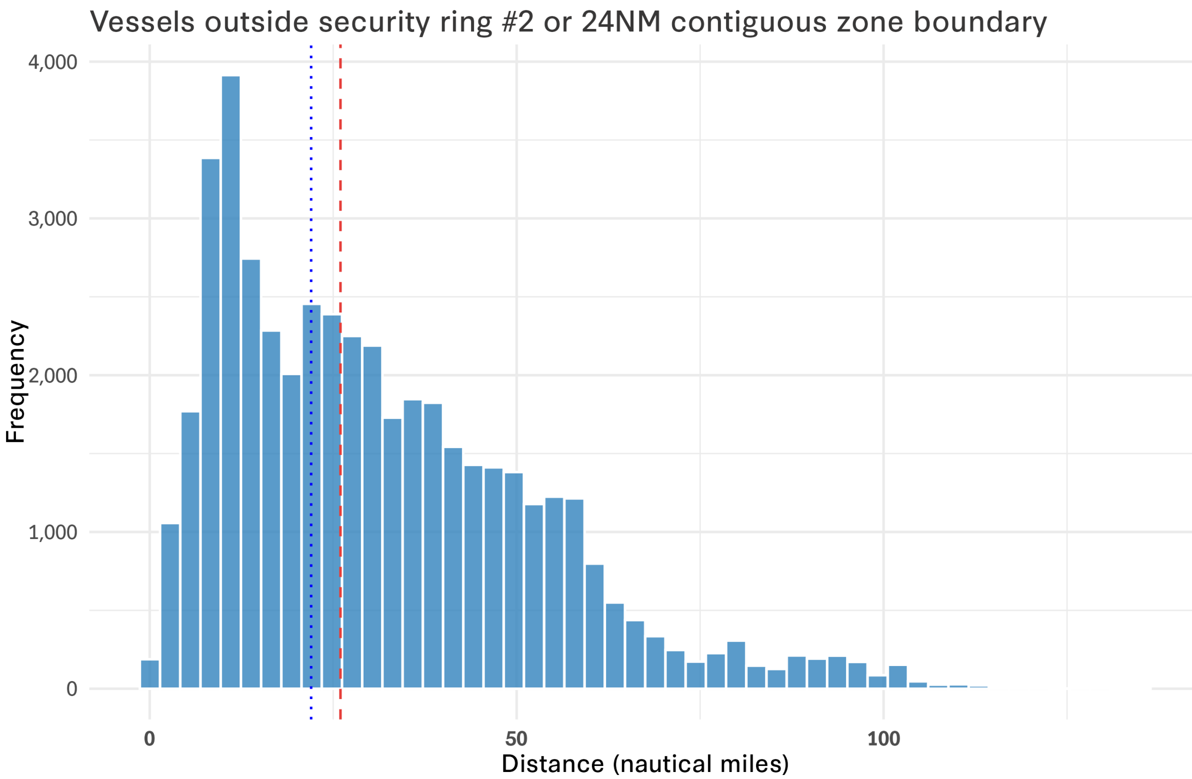
Next, the team analyzed the CCG movements using a kernel density estimation, a statistical method used to estimate where a vessel is most likely to have been located over a period based on AIS data–and clustered/binned into contour levels. For each year, the kernel density estimation function was facet-wrapped to calculate each percentile contour (25%, 50%, 75%, and 95%) that encloses a region where the vessel spent a certain proportion of its total observed time as shown in Figure 5.

Time-Series ADS-B Extraction and Dual Use Airfields/Airports

The research team constructed the ADS-B data frame using a combination of open-source data. Critical to the team's success was identifying patterns of Mode S Address used by PRC military aircraft. The team located publicly reported Mode S Addresses reported by ADS-B.NL, scraped the data, and then identified common Mode S patterns used by aircraft.[70] Next, researchers identified an open-source server hosting tail-watching community data from ADS-B receivers, including aircraft images, called hexdb.io.[71] Leveraging hexdb.io's Application Programmable Interface, researchers programmed a systematic loop to query—in line with permissions and timing queue permitted by the server to respect load and public use—over 300,000 unique combinations of Mode S Address based on the patterns identified from the publicly available data. This resulted in a dataset of over 200 unique aircraft with call signs, models, and reported owners/operators spanning the PLA Air Force, Navy, police, search and rescue, government entities, PRC research institutes, and more. Aircraft models and owners/operators deemed not likely to have been used for military purposes and Taiwan mission sets were dropped from the study, reducing the subset to approximately 102 unique Mode S Addresses. In addition, Aireon provided case studies of probable UAV activity based on publicly available information that depicts flight origins, destinations, patterns, and the associated Mode S Addresses to enrich the dataset. The transponder addresses do not correlate directly to any aircraft registries that identify these aircraft as UAVs, including the hexdb.io database. Not every Mode S Address returned signals. The team recognizes the limitation that Mode S Addresses do not represent the full fleet and capabilities of the PRC and that its dataset is only a subset. This represents a primary constraint and a factor as to why air traffic to military airstrips and dual-use airports are used as a proxy for military activity.

Once the unique identifiers (Mode S Address) were captured, the team used Optix's ADS-B module to define a travel space within mainland China and Taiwan to query results. To prepare a PiP analysis, the team constructed polygons for open-source and reported military airfields and dual-use airports using the OSM package in R and other open-source sites.[72] The team buffered the polygons to four kilometers to account for aircraft turning off their ADS-B close to landing and applied a PiP to extract the attributes of bases where aircraft traveled. This data frame was the foundation to calculate the air traffic shown in Figures 8, 10–11, the geographic visits in Figure 12, and the ping sums and averages in Tables 3 and 4.

Figure A1: Distribution of Nautical Miles Traveled to 24NM Contiguous Zone Boundary



Source: Author analysis of AIS data with shortest distance to the 24NM contiguous zone boundary.

Figure A1 shows the distribution of distance for each AIS observation. Given that the data slightly skews right, the research team focused on the median (denoted by the thin dotted blue line) rather than the average (dotted red line) to produce Figure 6. However, due to minimal-to-low variance at the daily level for distinct CCG vessels, the team opted for minimum averages for Figure 7.

Integrated Pressure Index

To estimate the daily pressure PRC applies to Taiwan, the research team consulted with our ROC naval expert to propose the following variables and formula to create a pressure index:

- N_{24t}: the distinct number of CCG vessels that penetrated the 24 NM contiguous zone boundary on a given day ($_t$)
- N_{SR1_t}: the distinct Number of CCG vessels in Security Ring #1 on day ($_t$)
- N_{SR2_t}: the distinct Number of CCG vessels in Security Ring #2 on day ($_t$)
- d_t: the average daily minimum distance in nautical miles of distinct vessels to the 24NM contiguous boundary
- λ: (Lambda) is a distance decay parameter of 8
- H_t^{SR1}: the average daily hours spent by CCG vessels within Security Ring #1 on day (t)

- H_t^{SR2}: the average daily hours spent by CCG vessels within Security Ring #2 on day (t)
- $Q_{0.01}$,$Q_{0.99:}$ Sample of 1st and 99th percentiles
- $DistanceScore_t$: converts distance to a 0-1 proximity intensity; closer vessels get higher scores
- $OuterApproach_t$: same-day pressure from ring activity adjusted by proximity to the 24 NM boundary
- $Breach_t$: separate escalation term for 24 NM penetrations
- A_{t-3}: the distinct PRC military aircraft on day t −3 (3 day lag)
- (δ): (delta) is a drill/exercise day value
- Z*: Represents a z score standardization formula
- Vessel Presence $Pressure_t$: Generates a baseline maritime pressure from CCG presence in Security Ring #1 of 50% and for each additional vessel beyond 1 in Ring #1, add 5%
- Security Ring #1 Loiter $Pressure_t$: Contributes maritime pressure from loitering behavior in the security ring #1, for every added 2 standard deviations of time, pressure increases by 15%
- Security Ring #2 Loiter $Pressure_t$: This is a threshold-based pressure add-on for prolonged time in security ring #2 where if loitering exceeds 1 standard deviation, pressure increases by 30%.

$$DistanceScore_t = \begin{cases} \exp\left(-\frac{d_t}{\lambda}\right), if\ (N_{SR1_t} + N_{SR2_t}) > 0 \\ \hline 0, Otherwsie \end{cases}$$

$$OuterApproach_t = (N_{SR1_t} + N_{SR2_t}) \cdot DistanceScore_t$$

$$Breach_t = \log(1 + N_{24_t})$$

$$z^*(x_t) = \begin{cases} \frac{x_t - \bar{x}}{s_x}, s_x > 0 \\ \hline 0,\ s_x = 0 \text{ or undefined} \end{cases}$$

To provide pressure behavior terms, the team relied on Tao-Hung Chang's advice to provide an assessment on the quantity of CCG vessels present versus time spent. As such the weights .15 and .30 represent an approach to help understand the level of pressure experienced. The data will at times record AIS signatures as CCG vessels are passing through zones that will carry less importance compared to a sustained presence/loitering activities.

$$Vessel\ Presence\ Pressure_t = .50 + .05\ \cdot \max(0, N_{SR1_t} - 1)$$

$$Security\ Ring\ \#1\ Loiter\ Pressure_t = .15 \cdot \max(0, [\frac{z^*(H_t^{SR1})}{2}])$$

$$Security\ Ring\ \#2\ Loiter\ Pressure_t = \begin{cases} .30, z^*(H_t^{SR2} > 1) \\ 0, otherwise \end{cases}$$

To distribute the elements of maritime pressure, the team generated weighted terms based on Tao-Hung Chang's suggestions as the following:

$$
\begin{aligned}
& MaritimePressure_t \\
& \quad = .30z^*(OuterApproach_t) + .20z^*\left(N_{SR2_t}\right) + .10z^*\left(N_{SR1_t}\right) + .25z^*(Breach_t) \\
& \quad + .10z^*(H_t^{SR1}) + .05z^*(H_t^{SR2}) + \ Vessel\ Presence\ Pressure_t \\
& \quad + \ Security\ Ring\ \#1\ Loiter\ Pressure_t \\
& \quad + \ Security\ Ring\ \#2\ Loiter\ Pressure_t
\end{aligned}
$$

Next, the formula integrates the air domain by including the effect of air pressure of distinct military aircraft on day t −3 (3 day lag).

$$
JointBlock_t = \frac{MaritimePressure_t + \ z^*(A_{t-3})}{2}
$$

$$
IPI_t^{raw} = JointBlock_t + \delta D_t
$$

With delta (δ) representing a value of .5 (drill bonus) and (D_t) is a binary indicator of 0 or 1 (ε{0,1}) the outcome sums to the IPI raw value.

$$
IPI_t^{clip} = \min(\max(IPI_t^{raw}, Q_{0.01}), Q_{0.99})
$$

Lastly, the team clips the IPI based on the daily minimum and maximum of the quantiles.

$$
IPI_t = 100 \cdot \frac{IPI_t^{clip} - \ Q_{0.01}}{Q_{0.99} - Q_{0.01}}
$$

Endnotes

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56 Operators of aircraft include the PLA Air Force, the PLA Army Aviation, and the Aviation Industry Corporation of China. Models vary but include UAVs, attack helicopters, and cargo and personnel transport planes. The Futures Lab’s internal dataset contains additional plane types; this study is based on a

subset created based on the pattern of aircraft to military airstrips and airports identified as being able to support a potential campaign against Taiwan.

57 This data was aggregated by the author from open sources, which remain unspecified to protect the availability of this information. The research team cross-validated sources by inspecting imagery of locations with PLA aircraft at dual use airfields/airports providing a level of moderate to high confidence. Moreover, the patterns of our ADS-B dataset showed flights to and from commercial/civilian airports lending additional evidence that the PLA benefits from dual use. For more information, please contact jmacias@csis.org. They are also available via paid platforms like Janes (https://www.janes.com). Not all 150 aircraft as detailed in the appendix were found; rather, year over year there are a total of 102 aircraft detected. Some Mode S addresses are likely changed among aircraft to avoid tracking by commercial entities.

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