A Defense of Taiwan with Ukrainian Characteristics: Lessons from the war in Ukraine for the Western Pacific

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Executive Summary

The war in Ukraine offers many important lessons for the defense of Taiwan against possible aggression by the People's Republic of China. The obvious differences between the theaters and the combatants must not be allowed to obscure the important changes in the character of war manifested in Ukraine that will likely apply to almost all future major conflicts. Some lessons will apply directly, since a successful amphibious invasion ends in ground combat. Others require abstraction and major adaptation. But the PRC is studying the war and drawing its own conclusions about how to prepare for future conflict in the western Pacific, and it behooves the US, Taiwan, and our allies and partners to do the same.

The Ukraine war is demonstrating dramatic changes in the character of war in five main ways:

1) The effectiveness of integrated air/missile defense (IAMD) against even intensive and complex air/missile attack (a phenomenon also visible in Iranian attacks against Israel);
2) The ability of enormous masses of tactical drones—millions of drones used on both sides—to create partially transparent battlefields and constrain combat to positional forms;
3) The ability of integrated drone-missile attacks including both aerial and maritime drones to achieve mission kills and even catastrophic kills of major and minor surface combatants;
4) The expansion of electronic warfare (EW) capabilities to scales and effects never before seen in combat; and
5) The emergence of an extremely rapid battlefield technological-tactical innovation cycle, driven largely by a race between drone and EW technologies, that can see major changes implement along a thousand-kilometer frontline in as few as two-three weeks.

The Air-Missile War

Both Russia and Ukraine have fielded integrated air/missile defense systems in response to increasingly complex attacks combining ground- and air-launched cruise missiles, ballistic missiles, and drones. These IAMDs have proven successful at preventing either side from achieving decisive effects even with massed strikes. The effectiveness of these IAMDs calls into question the ability of any state to rely on traditional missile systems to penetrate to their targets, a reality that should drive a reconsideration of Taiwan conflict scenarios that have assumed that high proportions of such systems would achieve their intended effects.

Both sides have responded to the development of these IAMDs by innovating strike packages and patterns to achieve temporary advantages. The Russians in particular have

experimented constantly with different combinations of drones, cruise missiles, and ballistic missiles to reconnoiter and penetrate Ukrainian air/missile defenses. Their approaches have alternated between attempting to saturate the defenses and finding weak points or vulnerabilities to exploit. Iran's two major attacks on Israel demonstrated (unsuccessful) efforts to implement some of these Russian best practices and innovate on its own.

The cost curve of the offense-defense race in the air has become a factor in systems design. The scarcity, expense, and difficulty of mass-producing high-end interceptors has forced Ukraine (and Israel) to design IAMDs that can allocate the cheapest and most available defense systems against targets they can destroy while preserving the rarest and most expensive systems for the hardest threats—and to adjust prioritization and integration dynamically as the character of attacks changes. Sometimes important innovations come from using the most mundane technologies—Ukraine lifted the burden of shooting down many drones from expensive systems by fielding mobile fire teams equipped with shotguns and rifles, for example.

The potential combatants in a Taiwan scenario are wealthier and better able to produce large quantities of exquisite systems, but they will likely find themselves constrained by the same realities—it is simply easier to mass produce inexpensive and less complex systems with which to overwhelm exquisite defenses, and defenders must be able to defeat such systems with simple and cheap defenses of their own. The resulting IAMD must be built, therefore, to optimize algorithmically for cost and availability as well as effectiveness.

Millions of Drones

The scale of the use of unmanned systems in Ukraine is difficult to internalize. The Russians and Ukrainians will likely have deployed and used more than three million drones in 2024. These drones range from hand-held quadcopters with ranges of about 10 kilometers to longer-range quadcopters (ranges up to 40-50 kilometers in one-way attack mode) all the way to fixed-wing drones with ranges beyond 2,000 kilometers. The Russians have reportedly already used well over 6,000 Shahed-type drones with ranges up to 2,500 kilometers. These drones perform a wide array of functions but have been particularly transformative in creating a nearly-transparent battlefield. Drone operators can see nearly every individual armored vehicle and many small infantry units across the battlefield in increasingly integrated common operating pictures and can strike almost anything they can see. This phenomenon has brought the war to its current positional character in which it is almost impossible for either side to make operationally-significant advances unless they can gain a temporary set of advantages (about which more below).

Small attack drones can achieve both mission kills (disabling the target temporarily) and catastrophic kills against tanks and armored vehicles. Larger drones have been used together with missiles to achieve both mission and catastrophic kills of major and minor surface combatants and (surfaced) submarines. Drone still suffer from important limitations and can only partially replace traditional artillery, rocket, missile, and bomb systems, but they have been far more successful in destroying armored vehicles en masse than in any previous conflict.

Drones at Sea

The Ukraine war is extremely unusual in that a state with effectively no navy has inflicted major naval defeats on a great power. Ukrainian forces using different combinations of maritime and aerial drones and missiles have sunk approximately one-third of the Russian Black Sea Fleet and driven it from its home base and headquarters at Sevastopol to a reserve base more than 200 miles to the east. Ukraine used a combination of drones and anti-shipping missiles to sink the Black Sea Fleet's flagship (an air defense cruiser), as well as numerous major and minor surface combatants and submarines (dockside). Ukraine's maritime drones have largely driven the BSF even from operating in the western Black Sea and have forced the Russians to develop and deploy extensive tactical and technical defenses. Ukrainian unmanned surface vehicles (USVs) have the range to strike Russian positions in the eastern Black Sea, but Ukrainian forces have not yet developed offsets for Russian defenses, especially the use of rotary-wing aircraft.

Electronic Warfare

Both sides have invested heavily in electronic warfare and have generated dramatic new capabilities. The Russians disrupted the 2023 Ukrainian counteroffensive partly by deploying jammers that disrupted GPS signals over a wide area and, in some cases, completely blocked almost all means of electronic communications. EW systems regularly disrupt drone operations at varying distances, and soldiers on both sides have personal counter-drone EW systems. Ukraine has reportedly become adept at using EW to disrupt Russian Shahed long-range fixed-wing drone operations, regularly disorienting significant percentages of the Shaheds fired.

Rapid Offense-Defense Cycling

Developments in EW have driven a very rapidly cycling race with drone developers, who constantly find ways to restore communications resilience in the face of new EW advances. The drone-EW race moves very rapidly, and significant changes can ripple across the entire thousand-kilometer front in two-three weeks. Developments take place at differential rates in three key areas: platforms (slowest, usually months); electronics (faster, often within a few weeks); and software (as fast as days in some cases). Both sides work to find and then block new frequencies, frequency-hopping, and other improved communications systems. Neither side has found a way to secure a long-term advantage in either EW or drone communications.

Neither side has developed a way to deconflict drone and EW efforts in the close fight, however, leading to extremely high rates of drone fratricide. Soldiers instinctively down any drone they see, and neither Russia nor Ukraine has fielded a trusted system to let soldiers know if a drone is friend or foe.

Implications for Taiwan

An integrated Tactical Reconnaissance-Strike Complex (TRSC) has emerged on both sides of the battleline comprised of drones and traditional fire/strike systems, and communications that has rendered successful operational-level maneuver prohibitively costly for the moment. Taiwan and the PRC could field suitably modified TRSCs for the ground forces that would face one another in the event of a successful PRC landing, but also as part of their maritime operations. The limited ranges of the most common drones can be offset by using the Taiwanese, Japanese, and possibly Philippines archipelagos to

their greatest potential. Seeding those archipelagos with tens or hundreds of thousands of long-range quadcopters could provide nearly continuous coverage from Penghu to Kyushu with only one significant gap. Supplementing long-range quadcopters with smaller and much more numerous hand-held quadcopters can give individual islands, including Taiwan, an opportunity for defense-in-depth against landings or waterborne attack. Integrating the feeds of all such systems can help ensure that the maritime battlespace remains nearly transparent by supplementing radar and satellite-based surveillance with low-altitude visual observation.

The fact that quadcopters cannot sink ships does not deprive them of great potential utility in disrupting an amphibious operation. Thousands of drones circling incoming ships can confuse and disorient them, overwhelm targeting and defense systems, and attack vulnerable intelligence collection and communications components. They may be able to achieve mission kills, enough of which on the right targets could force the abandonment of an amphibious operation, or support catastrophic kills by other systems.

Taiwan and its partners must also be prepared to defend against the PRC fielding of such capabilities. Ships make excellent EW platforms, for example, and could be used to disrupt communications at long distances. PRC aerial and maritime drones can also confuse, overwhelm, and achieve mission kills against essential Taiwanese, Japanese, and US vessels and ground-based systems.

Taiwan and its partners, finally, must be prepared for the requirement of extremely rapid and continuous adaptation under fire, even in a relatively brief conflict. The systems with which both sides start the war will likely be rendered ineffective before the war is over. Success may well go to the side that can innovate at scale more rapidly and can take advantage of that innovation through dynamic planning and flexible operations. The requirement to be able to field millions of drones is a requirement to be able to produce millions of drones rapidly, not to have them warehoused in advance.

Ukraine (and Israel) are demonstrating that free societies with robust innovation centers and the ability and willingness to support decentralized innovation and creativity as well as highly flexible planning and operations can hold off much larger and, in Ukraine's case, better resourced adversaries. Taiwan should take heart from this case study while exploring it closely for approaches that could be used, suitably modified, to defend the Republic of China.

Introduction

The war in Ukraine is leading to rapid warfighting developments that will change the character of contemporary warfare and offer Taiwan and its partners opportunities to conduct an effective defense against potential aggression by the People's Republic of China (PRC). The war in Ukraine, like most large and protracted wars, has brought about an intense innovation and adaptation cycle iterating much faster than in peacetime.[1] Several new technological phenomena fielded at scale in a major war for the first time have intensified this innovation cycle. These phenomena are exacerbating existing problems with maneuver warfare typically seen in wars between large, modern states while creating new challenges that are

particularly constraining offensive operations on both sides. These challenges present obstacles to Ukrainian efforts to liberate territory from Russian occupation and Russian efforts to overwhelm Ukraine and destroy Ukrainian statehood.

Russian and Ukrainian forces did not foresee how the innovation cycle would lead to a protracted positional war. Russia and Ukraine thus find themselves having to cope with the reality of protracted positional warfare and have readjusted their strategic approaches accordingly. The next belligerents to fight a major conventional war need not fall into a protracted war in which small areas remain actively contested over a long period and significant operational objectives prove elusive, however, if they proactively draw upon and implement the right lessons from Ukraine, suitably modified for their theaters and relative capabilities.

The Ukraine war offers many lessons relevant for Taiwan and its partners despite the very different geography and strategic challenges posed by warfare in the western Pacific. Taiwan would thus be wise to prepare to leverage the innovations made by both sides in Ukraine that have constrained offensive operations in order to degrade the People's Liberation Army's (PLA) offensive capabilities from the moment the PRC launches any aggression against Taiwan. The PRC is almost certainly paying attention to the developments in Ukraine, moreover, and Taiwan and its partners must therefore understand both how the PRC could leverage lessons from Ukraine and how they can do so in a way that gives Taiwan the advantage.

Several new technological phenomena fielded at scale in Ukraine and the imperative both Russia and Ukraine face to gain military advantage have contributed to the rapid innovation cycle. This innovation cycle has heavily influenced many stages of fighting, largely taking the form of a constant offense-defense race. Changes can proliferate across the 1,000-kilometer front in a matter of weeks—a phenomenon that could be relevant even to a relatively short conflict in the western Pacific. This extremely rapid innovation cycle will not be isolated to Ukraine but will instead very likely be a central feature in any future large-scale conventional war. Support for such a wartime innovation cycle and planning for operational efforts around the likely offense-defense race will be vital for preparations to defend Taiwan.

The war in Ukraine has seen both sides use several technological phenomena at scale that will characterize contemporary and likely future war:

1. Effective air and missile defense systems used at scale against massive and repeated drone, cruise, and ballistic missile salvoes;
2. Use of drones and cruise missiles to penetrate and degrade advanced layered air defense systems;
3. Use of millions of reconnaissance and strike unmanned aerial systems (UAVs or drones) and first-person view (FPV) loitering munitions;
4. Rapid, dynamic evolution of electronic warfare (EW) measures and counter-measures, including GPS jamming at scale and counter-drone EW; and

5. Use of air and maritime drones to destroy major surface combatants in port and at sea.[2]

Russian and Ukrainian forces face strong incentives to achieve technological advantage over one another and degrade any technological advantages that the other side gains. Even minor technological advantages offer each side an opportunity to inflict heavier losses on the other and make important gains on the battlefield. A relatively consistent parity in Ukrainian and Russian capabilities along the frontline between 2023 and 2024 has caused the war to assume a positional character and has thus far prevented both sides from pursuing significant battlefields gains through maneuver warfare. Allowing the adversary to achieve a capability advantage poses a strategic threat, offering the adversary the opportunity to make operationally significant advances and reconfigure the geometry of the battlefield before it resumes a positional character after an offsetting technological advance restores rough capability parity. In the current conditions of positional war any operationally significant advance becomes an outsized gain for one side and a pronounced loss for the other. The need to gain a capability parity advantage or, conversely, to restore capability parity when the other side gains an advantage is therefore especially urgent. Technological adaptations have contributed to this capability parity but have also offered both sides opportunities to break it, and the strong incentive to break or restore parity is the phenomenon driving the constant technological offense-defense race in Ukraine.

Technological innovation does not generate advantages that permanently disrupt or restore capability parity. A key aspect of the current offense-defense race is that innovation gives only temporary advantages before the adversary quickly deploys countermeasures that degrade or negate the effects of the innovation. In many instances Russian and Ukrainian forces then respond with countermeasures to the countermeasure in efforts to tip the capability balance in their favor. The temporary effect that new innovations have on the balance of capabilities means that several new innovations fielded at once or in relatively quick succession are required in order to break parity long enough to leverage the advantage for significant successful operations. Rarely has either side disrupted the capability balance through technological innovation long enough to leverage the benefits of their capability advantage in prolonged operational efforts, however. The temporary benefits of newly fielded innovations therefore create temporary windows of operational opportunity, and Russian and Ukrainian forces have increasingly appeared to time the fielding of new advances in the offense-defense race with new or intensified operational efforts specifically designed to take advantage of them. These dynamics in the offense-defense race have further incentivized quick developments in the iteration of innovations and countermeasures, and ISW has observed rapid offense-defense cycles iterating in periods as short as two-to-three weeks in Ukraine.[3]

These phenomena can occur in the case of PRC aggression against Taiwan in several ways. First, if the PRC attempts to initiate conflict through an air and missile campaign then Taiwan and its partners will have much greater opportunities to disrupt and defend against that campaign than many scenarios have assumed. The disruption of such a campaign could either protract it or generate a pause before the PLA began maritime operations. Second, pre-war adoption and adaptation of a number of technologies used in Ukraine at scale could potentially give Taiwan—or the PRC—asymmetric advantages in

the case of a maritime invasion operation. And third, the widespread pre-war adoption and adaptation of lessons from the Ukraine war could give Taiwan or the PRC significant advantages in the ground phase of an invasion scenario. All three cases could see the employment of innovations that are emerging in Ukraine in ways that protract a conflict and produce conditions analogous to the positional warfare that currently characterizes the war in Ukraine.

Russia and Ukraine have had to build out their apparatuses for identifying, developing, fielding, and iterating adaptations central to the offense-defense race as the war has progressed and have not always done so in the most expeditious fashion. It is not possible to predict all the exact adaptations that will be central to an offense-defense race between the PRC and Taiwan and its partners, but Taiwan and its potential partners can and should think about the systems and structures needed for responding to any future offense-defense race effectively and rapidly in addition to preparations they must make to take advantage of emerging technologies and techniques.

Ukraine has leveraged technological innovation as part of a strategy to offset Russia's superior materiel and manpower advantages and has illustrated how battlefield adaptations can allow countries to manage costs while inflicting asymmetric losses on their adversaries. Taiwan and its partners are similarly incentivized to prioritize such a strategy since the PRC has significant materiel and manpower advantages. Russia has sought to leverage its own significant manpower and materiel advantages over Ukraine to overwhelm Ukraine, and the Russian military command has consistently assumed that these advantages would allow Russia to achieve its operational and strategic objectives in Ukraine.[4] Ukrainian forces have used innovative tactics, more effective Western-provided capabilities, and domestically produced technological adaptations to offset these Russian advantages throughout the full-scale invasion.[5] Ukrainian leadership has articulated an overarching strategy since the start of 2024 of using widespread technological innovation to conserve Ukrainian manpower and resources while offsetting Russian military advantages — ultimately aimed at contesting the theater-wide initiative in Ukraine and restoring maneuver to the battlefield so that Ukraine can begin to liberate operationally significant territory once again.[6] This strategy has become even more salient as Russian President Vladimir Putin and the Russian military command have committed Russian forces to winning an attritional war against Ukraine.[7] Ukraine therefore must manage an attrition gradient against Russian forces over the long term to break the Russian theory of victory while pursuing its own strategy to conduct several subsequent campaigns that liberate operationally significant territory through maneuver.

Ukrainian innovation has already enabled Ukraine to manage this attrition gradient through reducing costs and inflicting asymmetric losses on Russian forces. Ukraine has leveraged lower-end and cheap systems to manage these costs and inflict these losses — most clearly shown by the Ukrainian use of cheap commercially available quadcopter drones and domestically produced first person view (FPV) drones. Ukrainian forces began to field cheap drones en masse by late Summer 2023 to conduct pervasive intelligence, surveillance, and reconnaissance (ISR) throughout the theater while also using these drones as a pervasive tactical fire element along the entire frontline.[8] Ukrainian forces

have used these drones to improve the accuracy of fire and strike elements and conserve ammunition stocks, particularly during times of scarcity brought about by delays in Western security assistance.[9]

In many instances lower-end and cheaper systems fielded in huge quantities have been able to achieve operational impacts as significant as those normally requiring scarcer and more expensive higher-end systems. A single cheap drone deployed by itself would have very minimal impacts on overall fire and ISR capabilities in any given sector of the frontline, but when small inexpensive drones are employed in the thousands or tens of thousands they can generate pervasive ISR and fire capabilities that allow them to create nearly transparent battlefields that largely preclude large-scale maneuver.[10] Higher-end and more expensive systems are by nature scarcer. They can only be massed in certain sectors and must be both protected and husbanded since they are generally difficult or impossible to mass produce. The Russians have even had to begin conserving and protecting their artillery tubes as losses among those systems, on which the Russian military in particular has historically relied, have reached levels concerning to Moscow. Mass can endow cheap and mass-produceable systems with capabilities and qualities in aggregate that are exponentially greater than those the individual system themselves have, and lower-end and cheaper systems thus provide more opportunities for leveraging the potential effects of mass. Their low cost and relative ease of production allows them to be used more widely across the theater and reduces the requirement of troops to husband them. Since there is currently no reliable way of destroying them before they are used, moreover, there is not yet a need to husband or protect them.

Cheap and lower-end systems cannot replace higher-end capabilities in every situation, however, and a key element of managing costs and inflicting asymmetric losses in Ukraine has been the integration of higher-end systems with lower-end systems. Effectively managing an attrition gradient requires allocating systems and capabilities to respond to and degrade enemy systems and capabilities that have comparable costs, preferentially using comparatively cheaper and lower-end systems when possible. Ukraine, for example, began fielding mobile fire groups equipped with rifles, machine guns, and other inexpensive and low-tech weapons in Spring 2023 to defend against Russian Shahed-136/131 drones that were becoming more abundant in Russia's sustained strike campaign against Ukraine.[11] The mobile fire groups allowed Ukrainian air defenders to conserve much scarcer and more expensive air defense interceptor missiles for targets such as aircraft, cruise, and ballistic missiles that only they could defeat. Cheaper drones, on the other hand, are not able to cause significant damage to many hardened Russian military facilities and higher-end equipment, and Ukraine must still use limited long-range strike systems for these targets.[12]

Russian forces have typically lagged behind Ukrainian forces when it has come to the innovation cycle both because Ukraine has greater incentivizes to field technological innovations and because Russia's generally centralized approach to command and control and industrial production raises obstacles to the rapid innovation that Ukraine's decentralized approaches favor. Russian forces have attempted to leverage their manpower and equipment advantages en masse through waves of costly frontal infantry attacks known as "meat assaults" and periodic large mechanized assaults.[13] These

attritional "meat assaults" have only facilitated marginal tactical gains, however, and the Russian military continues to prove inept at conducting effective mechanized maneuver.[14] The Russian military has also conducted theater-wide artillery fire at scales three to eight times greater than Ukrainian forces throughout the full-scale invasion, relying on larger stocks of artillery shells and on allies that have provided Russia with large quantities of shells.[15] The Russian military's use of mass supports Putin's theory of victory that Russian can win a war of attrition despite its inability to support successful operationally significant offensive operations.[16] Putin and the Russian military command appear to assess that Russia possesses enough resources to rely on mass to conduct consistent offensive operations as long as it takes to collapse Ukrainian resistance and outlast Western assistance.

This view on the advantages of Russian mass does not incentivize Russia to field innovations that conserve resources and inflict asymmetric losses, whereas Ukraine's manpower and materiel disadvantages have made such innovation crucial for the Ukrainian war effort. Russian forces have adapted and actively participated in the offense-defense race to prevent Ukraine from achieving capability advantage and to constrain Ukraine's ability to conduct significant, successful counteroffensive operations. Russian forces have also fielded new or notable capabilities ahead of Ukrainian forces on several occasions, but these innovations have appeared to focus on immediately supporting Russian offensive capabilities rather than on managing the overall attrition gradient. Russian forces have followed behind Ukrainian efforts to field capabilities that conserve manpower and materiel but have yet to abandon the reliance on mass that continues to produce disproportionate Russian manpower and equipment losses.

The PRC and Taiwan may find themselves in a similar dynamic based on the likely manpower and materiel disparities between them, although Taiwan's potential partners may influence how the belligerents view these disparities. The PRC will almost certainly have manpower advantages over Taiwan and its potential allies, although it is unclear if it will have the materiel advantage or, if it does, that its materiel advantage will be even close to the one Russia has over Ukraine. The United States and its allies have made clear that they will not fight against Russia in Ukraine, whereas most Taiwan Strait scenarios envisage the US military and possibly the Japanese and other western Pacific militaries engaging in ways that would change the materiel balance dramatically. Even if the PRC has both manpower and materiel advantages over Taiwan and its potential partners, moreover, it is not the case that the PRC leadership will display the same unconcern with managing costs and inflicting asymmetric losses that Putin has shown.

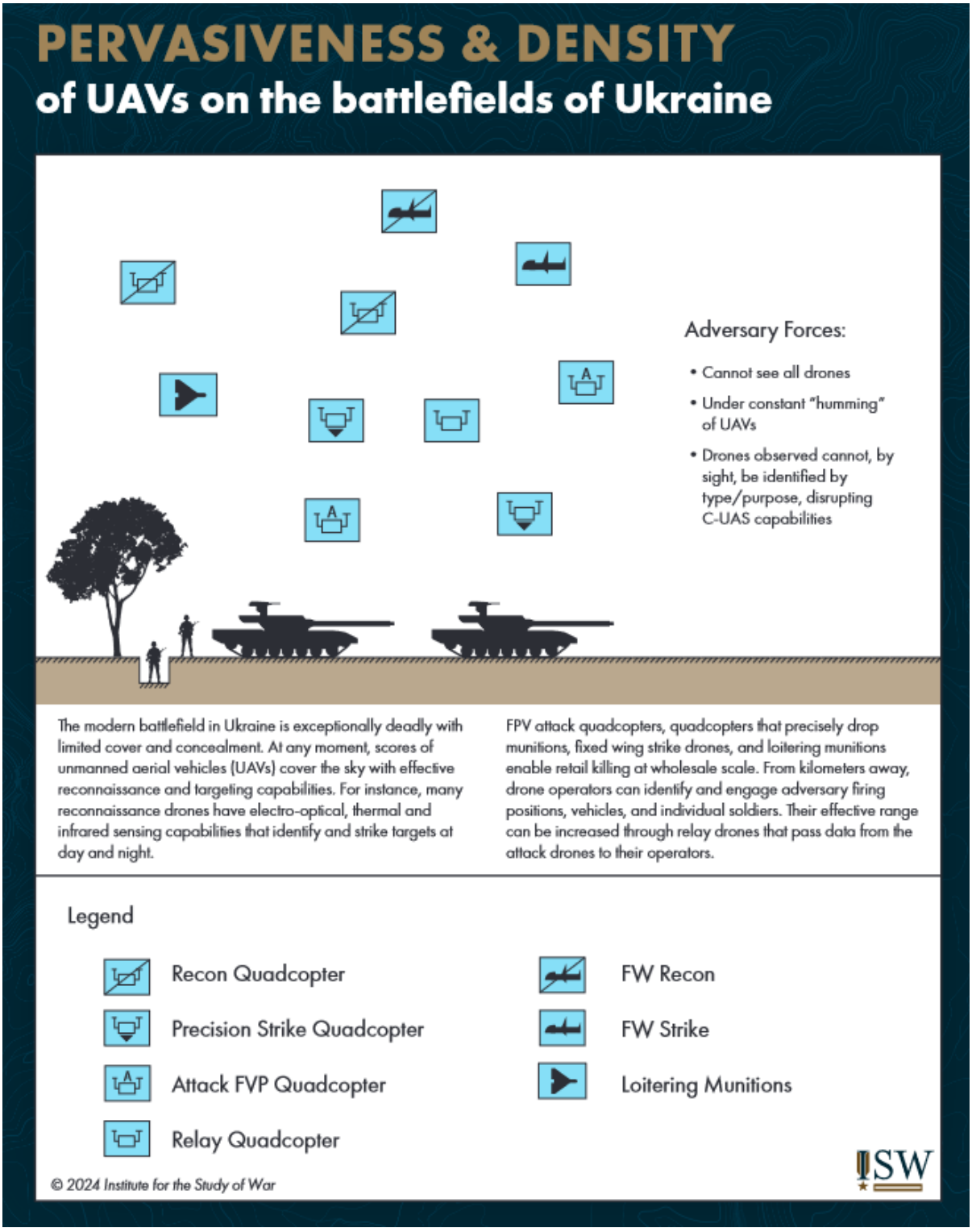
The war in Ukraine offers a number of concrete lessons about the operational effects generated by the use of existing and new technologies at scale that Taiwan and its partners will likely encounter in the event of PRC aggression, and several of those operational effects offer opportunities to upset the PLA's calculations. This paper prioritizes lessons from long-range strike campaigns in Ukraine and from maritime interdiction efforts since those are most obviously and immediately relevant to a Taiwan invasion scenario. (The Ukraine war also offers lessons for the ground phase of a PRC invasion of Taiwan, but this paper will not explore those lessons in detail because few public scenarios of a PRC invasion of Taiwan

consider carefully the ground war that will likely follow a large-scale PLA landing.) The lessons from Ukraine suggest that capabilities demonstrated in Ukraine offer Taiwan and its partners opportunities to delay, disrupt, and degrade PLA long-range strike campaigns and maritime interdiction or invasion efforts.

The war in Ukraine is the first major conflict to see air and missile defense systems used at scale against massive and repeated drone and missile salvos and has shown that effective defense against sustained strike campaigns is possible. The war in Ukraine shows that Taiwan and its partners should not discount successful air/missile defense against a hypothetical PLA bombardment of Taiwan and long-range strike campaign. Russian forces have conducted a sustained missile and drone strike campaign against Ukraine since October 2022 that has included multiple salvoes with over 100 missiles.[17] This strike campaign has not achieved decisive effects, however, due to limited but effective Ukrainian air defense and the overly ambitious objectives of the strike campaign. Ukraine has fielded modern Western air defense systems that have proven quite effective at intercepting cruise missiles and ballistic missiles.[18] The PLA does possess real hypersonic missiles (unlike the Kinzhal aeroballistic missile that Russia claims to be hypersonic) that modern air defense systems have not yet demonstrated a capability to intercept, but these scarce and expensive weapons will be exceptions, however significant, to the case that modern air defense systems have made for themselves in Ukraine.[19] If Taiwan and its partners can establish a wide and effective air/missile defense umbrella with modern air/missile defense systems, then the large stocks of missiles that the PLA has acquired will not necessarily translate into a decisive strike campaign. Both Ukrainian and Russian long-range strike campaigns offer additional lessons for managing air defense requirements, generating operational pressures on adversaries, reconfiguring strike campaigns as they protract, and hardening and adjusting support and logistics facilities in the event that interception proves too difficult.

The war in Ukraine is also the first major conflict to see opposing sides use reconnaissance and strike drones and electronic warfare (EW) measures and countermeasures in tandem with existing strike and fire capabilities at scale. ISW recently published "Ukraine and the Problem of Restoring Maneuver in Contemporary War," which coined the expression Tactical Reconnaissance Strike Complex (TRSC) — the combination of pervasive tactical reconnaissance, primarily by drone; drone-corrected precision artillery fire; precision munitions delivered by fixed- and/or rotary-wing aircraft; drone-launched precision munitions; and large numbers of FPV loitering munitions with support from extensive offensive and defensive electronic warfare systems and operational and strategic reconnaissance assets.[20] Soviet and Russian military thinkers separated fire systems based on whether they achieved operational effects — Reconnaissance Strike Complex (RSC) — or tactical effects — Reconnaissance Fire Complex (RFC).[21] Russian and Ukrainian forces have merged operational and tactical systems together to achieve direct tactical effects but have yet to integrate long-range strike systems effectively into efforts to conduct or defend against large-scale operational efforts, thus leading to the term TRSC.[22] The PRC and Taiwan and its partners may be able to field distinct RFCs and RSCs with the new technological phenomena on display in Ukraine without merging the two into a TRSC, although the

TRSC has arisen in Ukraine because of the difficulty of establishing an effective RSC in a war between large states, and the PRC and Taiwan and its partners will almost certainly face the same difficulties.



The TRSC in Ukraine is not a set of integrated weapons in which all components have fixed capabilities and relationships with one another, but instead is a conceptual system in which the characteristics and capabilities of components can rapidly change and the relationships between components can vary. This phenomenon has made the TRSC particularly prone to rapid development. The TRSC has been the central element of the war in Ukraine around which adaptation have developed, specifically due to the offense-defense race between drone and EW capabilities. Adaptations occur at differential rates among the platforms in the TRSC and their critical electronics and software, and ISW has generally observed the most rapid changes occurring in software followed by changes in electronics and then platforms.[23] The TRSC is a very dynamic system, with components constantly in flux and variations in capability and intensity across the frontline resulting from bottlenecks and limitations in production, deployment, and implementation. Human factors are a common limiting factor on both sides—some commanders are reluctant to use or rely on new systems while others embrace them enthusiastically, for instance. The dynamism of the TRSC generates vulnerabilities and opportunities for both attackers and defenders and has allowed both sides to partially degrade the adversary's TRSC or exploit limited deployments or implementations of it in certain places to support ground operations. The TRSC's dynamism and flexibility also creates the ability to rapidly respond to setbacks and restore its functionality when degraded or disrupted.

The TRSC has allowed visual- and sensor-based reconnaissance to generate near transparency that has largely precluded effective operational maneuver along the frontline in Ukraine and is the main factor giving the war in Ukraine its positional character today.[24] "Ukraine and the Problem of Restoring Maneuver in Contemporary War" extensively examines how to neutralize an adversary's TRSC, and many of those observations will likely hold true for a potential PRC war of aggression against Taiwan. The TRSC as described in those observations relates to ground warfare, but the TRSC is not a concept isolated to ground warfare and can emerge in maritime theaters. Taiwan and its partners should reflect on how to field their own TRSC and degrade a PLA TRSC in the event of land warfare on the island of Taiwan while also focusing on how Taiwan and its partners could establish a modified maritime TRSC over the Taiwan Strait and along the first island chain to support critical maritime interdiction efforts.

Discussions along these lines are already underway on both sides. The PLA is increasingly focused on integrating drones into military operations, including naval operations, and US officials have publicly talked about possible plans to create a drone "hellscape" to deter the PRC from invading Taiwan.[25] Previous studies have recommended using drones to achieve pervasive ISR, and there are many public discussions about using drones as fire and strike elements in the Taiwan Strait.[26] ISW offers the more integrated conception of the TRSC as an organizing principle for developing drone-based capabilities at sea in deterring and defeating PRC aggression against Taiwan. The TRSC will look different in the Taiwan Strait and along the first island chain from the way it does in the flat steppe land of Ukraine, to be sure, and while this paper will offer some key points for considering those differences it does not intend to extensively explore how Taiwan and its partners should go about establishing the TRSC at sea.

The war in Ukraine has also seen the first use of air and maritime drones to destroy major surface combatants in port and at sea and the widespread use of drones in precision strikes against naval targets. Ukrainian forces have conducted a successful maritime interdiction campaign of their own against the Russian Black Sea Fleet (BSF) since Summer 2023 — a notable feat considering that Ukraine does not have a significant navy.[27] Ukrainian forces leveraged maritime drones, aerial drones, and long-range missiles to conduct this interdiction campaign and have so far damaged or destroyed roughly one-third of the BSF as of Summer 2024.[28] Ukraine's use of maritime drones and combined strike packages against the BSF offers one of the clearest examples of how to conduct effective long-range precision strikes against naval targets using a mix of lower-end and high-end systems. The Ukrainian maritime interdiction campaign will seem incredibly limited compared to the maritime interdiction efforts in a possible war between the PRC and Taiwan and its partners, of course. The BSF had only two ports from which to operate in the Black Sea, limiting Russian naval positioning that could have better protected the BSF from the Ukrainian interdiction effort.[29] Russian forces also could not move BSF vessels out of the Black Sea or reinforce them because the Montreux Convention prohibits the transit of warships through the Turkish Straits in wars to which Turkey is not a party, further degrading the Russian Navy's ability to defend against or respond to Ukrainian precision strikes.[30] There will be no such limitations in the Indo-Pacific, on the other hand, and the size of the theater will somewhat complicate long-range maritime interdiction efforts. The waters between the PRC and Taiwan are extremely narrow compared with the Black Sea, on the other hand, and would be far more crowded with People's Liberation Army Navy (PLAN) vessels in the event of an invasion than the Black Sea ever was by Russian ships. It is thus easy to overstate the importance of the size of the western Pacific theater as a way of dismissing lessons from the Russia-Ukraine war. Belligerents in the Indo-Pacific will still conduct the types of strikes that Ukraine conducted against the BSF, in any event, and lessons from these Ukrainian strikes offer insights into the promise such operations hold in maritime campaigns.

The current Russian and Ukrainian militaries are less technically sophisticated and more poorly supplied than the PLA and the militaries of the United States and its Asian allies to be sure. The ability of the PRC and of Taiwan and its partners to field more advanced technologies and systems does not render the lessons from Ukraine irrelevant, however. Russian and Ukrainian forces have employed many of the lower-end systems that they have in Ukraine because their economies are unable to support fielding more exquisite systems at scale. Both Ukraine and Russia have struggled with gradual mobilizations of their defense industrial bases (DIBs), due to a combination of political and economic constraints, and have access to far fewer resources for innovation than their Western or Asian counterparts. The PLA and Taiwan's partners will be resourced by much larger economies that have extensive access to components parts for critical high-end systems and the human and technological capital to field emerging technologies. The lessons from Ukraine are still relevant, however, even if the technological phenomena fielded in Ukraine end up being less exquisite than the versions fielded in a war between the PRC and Taiwan and its potential allies. Many of the more exquisite technologies that the PRC and Taiwan and its allies may field in the Indo-Pacific will likely be more advanced versions of the systems seen in Ukraine and subject to the same lessons, constraints, and

operational considerations. The overarching lessons from Ukraine about the importance of the innovation cycle, managing costs and inflicting asymmetric losses, and maintaining or breaking out of parity will be central aspects of a war over Taiwan.

The highest-end systems in the arsenals of the PRC and of Taiwan and its partners, moreover, remain scarce because of their cost and the difficulty of mass producing them, and are at risk of being rapidly exhausted in an extremely intensive initial campaign. Neither the PRC nor the United States and its allies and partners should thus assume that they will be able to fight only with their most exquisite capabilities or dismiss the possibility that an initial intensive effort to achieve decisive effects could fail and force them to fall back on the use of cheaper and more plentiful but far simpler systems.

The belligerents in a Taiwan scenario will likely field higher-end systems than the belligerents in Ukraine but will likely replicate Russia's and Ukraine's mass use of lower-end systems in any event. The PRC and Taiwan and its potential partners will face different cost considerations than Ukraine and Russia, but the imperative to manage costs even for them will likely result in the mass use of relatively cheaper systems. While it is unclear what those cheaper systems will exactly look like, no one should expect a theater filled with exquisite high-end systems fielded en masse and certainly not throughout anything but an extremely short conflict.

Lessons from Long-Range Strike Campaigns in Ukraine

The war in Ukraine illustrates that modern states have effective capabilities to defend against massive and prolonged missile and drone strike campaigns. Russian forces conducted a mass bombardment against Ukraine at the outset of the full-scale invasion in February 2022 and have conducted a regular and nearly continuous missile and drone strike campaign throughout Ukraine since October 2022. This campaign has not achieved decisive effects despite employing thousands of missiles and drones— in large part due to the effectiveness of modern air/missile defense systems and Ukrainian efforts to create an effective and sustainable air defense umbrella to offset significant limitations on the number of available modern air defense systems and interceptors available to it. Russia's long-range strike campaign in Ukraine has also illustrated that such campaigns are ill-suited to achieve decisive effects unless states acquire a massive arsenal of precision-strike weapons that can overwhelm their adversaries' air defenses. The PLA has accumulated a stock of at least 3,150 long-range precision missiles, which will likely be sufficient to support a prolonged strike campaign.[31] Taiwan and its potential partners will have much greater access to modern air defense systems and interceptors than Ukraine, however, and Taiwan will not be essentially defenseless against cruise missiles and ballistic missiles as Ukraine was before the arrival of Western-provided air defense systems. The PLA's hypothetical bombardment campaign against Taiwan in the lead up to a landing operation and invasion need not be decisive, or even particularly effective at hitting targets, if Taiwan and its partners proactively prepare for conducting an effective sustained air defense effort.

The recent failed Iranian attacks on Israel show what the most advanced missile defenses can do against moderate missile barrages, in fact.[32] This

paper will not explore those cases in detail, but it is important to note that their lessons must not be overdrawn—Israeli missile defenses, supported by the United States, are likely the very best in the world, whereas Iranian missiles are limited in both number and capabilities. Taiwan should likely expect to be able to mount a defense against PRC air/missile campaigns somewhere between the one Ukraine has mounted and the one Israel and the United States have demonstrated. The Ukraine case is worth studying as a likely lower-bound of the effectiveness of such missile defenses that Taiwan should be able to achieve even as it aspires to Israeli levels of capability.

Modern air defenses have proven effective at intercepting modern missile systems and long-range strike drones in Ukraine. Many modern air defense systems in use in Ukraine have proven highly effective at intercepting Russian cruise missiles and will likely be as effective against comparable PLA cruise missiles. Russian ballistic missiles have proven harder to intercept in Ukraine, however, and a more limited number of modern air defense systems — in Ukraine only the American Patriot batteries— appear able to intercept such missiles.[33] Russian forces have conducted 14 notably large combined strikes since seizing the theater-wide initiative in Fall 2023 about whose composition ISW has observed detailed reports.[34] Russian forces launched 544 Shahed-136/131 drones and 836 missiles as part of these 14 large strike packages, and Ukraine on average has shot down 92 percent of the Shahed drones and 64 percent of the missiles. The strike packages consisted of a total of 648 cruise missiles, 142 ballistic missiles, and 46 "Kinzhal" Kh-47 Aeroballistic missiles. Ukrainian air defenders have demonstrated on average a 77 percent interception rate for cruise missiles, a nine percent interception rate for ballistic missiles, and a 26 percent interception rate for Kinzhal missiles across these 14 strikes. Russian forces conducted these 14 large combined strikes during a period of pronounced Ukrainian air defense missile shortages caused by delays in Western security assistance, and since the resumption of US aid in Summer 2024 Ukrainian forces have demonstrated a 74 percent missile interception rate against large Russian strike packages. Ukrainian forces have also improved their ballistic missile interception rate to 22 percent and their Kinzhal interception rate to 40 percent during large Russian strikes since the resumption of US aid.

**Note on strike data: ISW compiled this data from Ukrainian reporting of Russian drone and missile strikes. Ukrainian officials have offered thorough reporting of particularly large missile and drone strikes but have provided less clear and detailed reporting about smaller individual strikes that Russian forces conduct along the frontline and against rear areas daily. Reporting specifically on the Russian use of Iskander missiles and S-300/S-400 missiles periodically lacks specificity. ISW collects data on Russia's daily strike campaign against Ukraine but has chosen to present a breakdown of larger strike series since clearer observations can be made from the data provided on these strikes.*

Russia has only fielded limited hypersonic capabilities in Ukraine to date, and the PRC notably has developed far more extensive hypersonic capabilities that can complicate the effectiveness of modern air defense systems. Russian officials claim that Kinzhals are hypersonic missiles but they technically are not, and Russia has only fielded one type of

hypersonic missile — the Zircon hypersonic cruise missile — in Ukraine to date in a very limited capacity.[35] Very limited hypersonic use against modern air defense systems in Ukraine has not revealed just how effective modern air defense systems can be against hypersonic missiles, although the effectiveness of anti-missile systems against the Kinzhal suggests that missiles must be truly hypersonic to make a material difference in interception rates.

Ukraine has started to conduct effective joint air defense using both aircraft and ground-based systems at scale, and joint air defense in Ukraine and elsewhere has proven especially effective at defending against large, combined strike packages. Ukrainian air/missile defense has relied almost entirely on ground-based systems for most of the war, but Ukrainian officials have long indicated that Ukrainian forces aim to conduct joint air defense with ground-based air defense systems and air-to-air missiles should it receive enough modern aircraft from the West.[36] Ukraine proved the effectiveness of even a partial joint air defense using a limited number of Western-provided F-16 fighter jets in its response to the largest Russian strike package since the start of the full-scale invasion on August 26, 2024 — during which Ukrainian forces demonstrated an 80 percent missile interception rate.[37] Israel and its partners leveraged a joint air, ground, and naval missile defense to defeat a mass Iranian missile and drone strike on April 13, 2024, in which Israeli and partner forces intercepted almost all of 320 air targets launched at Israel except for several ballistic missiles.[38] Israel and its partners similarly largely defeated a barrage of 180 Iranian ballistic missiles on October 1, 2024.[39] Russian forces often launch drones and missiles from throughout occupied Ukraine and in close proximity to Ukraine from within Russia, affording Ukrainian air defenders a fraction of the time that Israel and its allies leveraged to successfully blunt the Iranian strikes. The time and distances that Taiwan and its allies will have to conduct joint missile defense will resemble the greater operational space seen in the Iranian strikes against Israel for some areas of the first island chain but will resemble the more constrained operational space seen in Ukraine for the island of Taiwan itself. Taiwan and its potential allies have greater aviation capabilities than Ukraine to leverage in conducting a joint missile defense at scale, although the People's Liberation Army Air Force (PLAAF) may attempt to contest airspace in a manner that the Russian Aerospace Forces (VKS) have not attempted in Ukraine.

Ukraine has leveraged lower-end air defense systems and novel tactics and technologies to create a layered air defense umbrella and manage air defense costs and requirements. Prolonged strike campaigns and air defense efforts require managing missile, drone, and air defense missiles stocks while attempting to force one's adversary to expend more missiles, drones, and interceptors. Both Russian and Ukrainian forces have faced situations in which they have depleted their stocks for strike campaigns and air defense efforts, respectively, which have generated decreased strike tempo on the one hand and critical air defense limitations on the other. The first phase of the Russian strike campaign that Russian forces launched in October 2022 and conducted through Winter 2022-2023 heavily taxed Russian missile stocks and likely lowered them to critical levels.[40] This prompted a decreased tempo of Russian strikes and a pause in large missile and drone salvoes during Spring and Summer 2023 as Russian forces addressed missile production capacity, acquired more Shahed drones from Iran and started to acquire

ballistic missiles from North Korea. Russia began expanding domestic Shahed production capabilities to establish a precision-weapons arsenal that could support a more regular and sustained strike campaign.[41] Ukraine faced a critical air defense missile shortage in Spring 2024 due to months-long delays in Western security assistance that allowed Russian forces to conduct more effective and devastating strikes against Ukrainian energy infrastructure without necessarily intensifying the overall strike campaign.[42] Just as breaking or maintaining parity in military capability along the frontline is crucial for Ukrainian and Russian operational efforts, maintaining or gaining an advantage in strike and air defense capabilities is critical for how the Russian strike campaign impacts the wider Ukrainian war effort.

Ukraine's air defense effort under the conditions of limitation and scarcity illustrates the importance of configuring a layered air defense umbrella that allocates defensive capabilities to the appropriate corresponding threats and costs. Russian forces, for example, have specifically leveraged more widely available and cheaper Shahed-136/131 drones in attempts to overwhelm Ukrainian air defenses and force Ukraine to expend scarce and costly air defense interceptors on those inexpensive drones.[43] Ukrainian officials acknowledged that expending an air defense missile for one Shahed drone was a bad tradeoff that would eventually degrade Ukrainian air defense missile stocks, and Ukrainian forces began fielding mobile fire groups in Spring 2023 to respond to Shahed drones while conserving air defense missiles for Russian missile strikes as noted above.[44] Ukraine's limited number of US-provided Patriot air defense systems, which are the only Ukrainian air defense systems that have proven capable of intercepting Russian ballistic missiles, requires further layering within Ukraine's air defense umbrella.[45] Ukrainian forces are incentivized to rely solely on other modern air defense systems and Soviet-era air defense systems modified to launch Western-provided surface-to-air missiles in their response to Russian cruise missiles in order to conserve Patriot systems for Russian ballistic missiles. Ukrainian air defense limitations continue to force the Ukrainian command to make difficult choices about which areas and potential targets receive air defense coverage from ballistic missile strikes, however. Ukrainian forces have also started to leverage new technological capabilities, primarily electronic warfare (EW), to further offset pressures on Ukraine's modern air defense systems. Ukrainian officials and sources have indicated that Ukrainian EW is consistently disrupting radar-guided Shaheds, causing the drones to change course and crash far from their intended targets after running out of fuel.[46] Ukrainian officials have also suggested that Ukrainian forces have leveraged EW to degrade the effectiveness of some Russian missiles.[47]

Effective Ukrainian air defense has generated continuous experimentation and adaption in Russian strike profiles and tactics. Russian forces have increasingly focused on employing and adapting large, combined strike packages using various combinations of drones, cruise missiles, and ballistic missiles intended to identify and exploit vulnerabilities in Ukraine's air defense umbrella.[48] Russian forces have experimented with various strike profiles and have generally settled on packages that include a large number of drones and cruise missiles meant to map out and overwhelm Ukrainian defenses while a smaller number of ballistic missiles penetrate them.[49] Russian forces also switch between different strike packages to achieve different effects. They sometimes use packages with a large number of Shahed drones and a low number of

missiles to reconnoiter Ukrainian air defense assets and sometimes prefer packages with a moderate number of cruise missiles to fix Ukrainian air defenses in specific areas for a time.[50] Russian forces are also continuing to experiment with the timing and phasing of how they launch strike packages and with different flight paths to test the responses of Ukrainian air defenses.[51] Russian forces are fielding technological adaptations that aim to reduce the observability of their missiles and drones to make them harder to detect and intercept.[52] These efforts appear to be intermittently effective but unreliable. Russia's experimentation and adaptations in its strike campaigns are highly and sometimes rapidly iterative based on Ukrainian air defense responses to each individual strike series. This interactivity is a subset of the overall offense-defense race that characterizes the war in Ukraine.

Ukrainian strike campaigns for their part have forced Russian forces to undertake defensive mitigations on several occasions when Russian forces were unable to intercept the strikes either at all or in a cost-effective way. Ukrainian forces conducted a series of HIMARS strikes against Russian ammunition depots and airfields throughout occupied Ukraine in Summer 2022 at a time when the Russians had no ability to intercept or interfere with the HIMARS system, prompting Russian forces to disperse ammunition storage facilities and aviation assets in ways that degraded the efficiency of Russian logistics and aviation operations at the time.[53] The Russians appear to be still unable to intercept HIMARS, although they have developed the ability to interfere with their navigation systems.

Repeated Ukrainian long-range strikes against Russian Black Sea Fleet (BSF) facilities and ground lines of communication (GLOCs) in and surrounding occupied Crimea in Summer 2023 prompted Russian forces to start hardening these facilities and GLOCs.[54] Ukrainian drone strikes against oil depots, ammunition warehouses, airfields, logistics facilities, and military industry in rear areas within Russia in 2024 have prompted limited dispersals of military materiel and equipment and various efforts to harden facilities across a wide area of the Russian Federation.[55] These defensive mitigations are an alternative means to offset costs, pressures, and requirements for air defense assets and manage capability parity over the course of a prolonged strike campaign and air defense effort. Russia has the systems needed in principle to defend against any given Ukrainian drone strike package, for example, but deploying those systems to cover all the potentially important targets Ukraine might hit would be prohibitively expensive. The Russians have concentrated extensive air- and missile-defense assets in an effort to defend occupied Crimea and Russian GLOCs, on the other hand, but at the costs of depriving other areas of the front line of coverage and of exposing rare and expensive Russian missile-defense systems to Ukrainian strikes.

Detailed examination of Russian and Ukrainian strike campaigns and defensive responses to them exposes the complicated trade-offs involved in such an offense-defense race. Systems exist in principle to defend against all but the most advanced hypersonic missiles, but some of those systems double as effective long-range air defense assets and all of them are scarce and expensive. The defender's art is to optimize the deployment of such assets in a layered way that uses them only against targets that only they can engage while relying on a network of other, cheaper and more plentiful, systems to engage targets

easier to destroy. Even that approach is insufficient, however, and must be coupled with thoughtful calculations of risk in order to identify facilities and systems that absolutely must be protected while consciously exposing less valuable or more easily replaceable systems to enemy fire. Low-tech approaches such as hardening infrastructure can also help force the attacker to use limited high-end means, but such approaches take time and can also be very expensive. Waiting until the war has begun to harden facilities will likely doom this effort to failure, at least during the initial period of war. The attacker likewise must learn to optimize strike packages to try to force the defender to use scarce and expensive assets against less valuable strike systems and/or overwhelm defenses at predetermined key points. These strike campaigns also demonstrate the importance of using the strikes themselves as means of near-real-time reconnaissance and, conversely, of limiting the intelligence value each strike provides the attacker.

Russia's failed strike campaign to destroy Ukraine's will to fight in Winter 2022-2023 shows that strike campaigns that target will are costly undertakings that remain unlikely to succeed. The long history of strategic bombing campaigns aimed at breaking the enemy's will offers few if any examples of a successful such effort, and the Russian campaigns thus far have been no exception. Russian President Vladimir Putin and the Russian military command initially launched the Russian missile and drone strike campaign against Ukraine in October 2022 aiming to completely collapse Ukraine's energy infrastructure in hopes that harsh winter conditions would degrade Ukrainian morale and ultimately erode the Ukrainian nation's will to fight. Russian missile and drone strikes in Winter 2022-2023 did degrade Ukrainian energy infrastructure and inflicted unpleasant persistent blackouts throughout Ukrainian cities, but Russian forces failed to collapse Ukraine's energy grid due to their inability to maintain a high tempo and intensity of strikes that could have overwhelmed Ukraine's expanding air defense umbrella and cause enough damage to energy infrastructure.[56] ISW continues to assess that the collapse of Ukraine's energy grid alone would likely not destroy Ukrainian will to fight.[57] Targeting will is a massive undertaking with indeterminate requirements for achieving the objective, and strike campaigns that do not achieve decisive effects will likely fail to break will. The effective air defense capabilities fielded in the war in Ukraine suggest that strike campaigns that can achieve decisive effects will be incredibly rare in wars where belligerents have access to such capabilities.

Russian efforts to eliminate Ukrainian resistance at the outset of the full-scale invasion suggest that strike campaigns without mass missile stocks cannot eliminate capabilities and resources swiftly. Russian forces conducted a series of missile and air strikes in the first days of the full-scale invasion aimed at grounding the Ukrainian Air Force, crippling the Ukrainian Armed Forces, and degrading Ukraine's command and control (C2) and ability to redeploy and commit forces to a rapidly changing frontline.[58] Russia forces appeared unwilling to expend the majority of their missile stocks at the outset of the full-scale invasion or field aviation at scale over Ukrainian cities to conduct large-scale bombardments campaigns, likely viewing the expenditure of the majority of Russia's missile stocks or large aviation losses as too costly for what the Kremlin planned as a quick expeditionary military operation to depose the Ukrainian government and destroy Ukrainian statehood.[59] Russia's missile stocks at the

outset of the full-scale invasion likely did not afford Russian forces the ability to launch and sustain a massive opening strike salvo without expending their stock of precision weapons almost entirely.[60] The Russians assumed before the invasion that Ukrainians would not resist strongly and that many Ukrainians would support the Russian attack to overthrow their own government, and this assumption also conditioned the relative restraint and ineffectiveness of the Russian pre-invasion air campaign. This incident highlights a dilemma that the PRC will also have to confront. A militarily prudent air campaign is highly intensive and destructive, including of infrastructure the invader seeks to capture intact for its own use. An intense air campaign, moreover, generates many casualties that can push victims to oppose rather than welcome a subsequent invasion. Calibrating an air campaign before a war of conquest is thus a challenging undertaking.

Russian forces have used long-range strikes to fix limited Ukrainian air defense assets in place in order to open axes of air attack in key sectors of the front. Ukraine lacks enough air defense systems to provide even air defense coverage across all of Ukraine, and Russian forces have conducted a consistent series of strikes, sometimes at a low intensity, in part to force Ukrainian forces to concentrate those air defense systems on protecting larger population centers far from the front instead of providing coverage for front line units.[61] Fixing Ukrainian air defenses away from the frontline has become more operationally significant as Russian forces increasingly came to rely on fixed-wing aviation to conduct mass glide bomb strikes against Ukrainian frontline positions in 2024 as part of their efforts to sustain offensive operations.[62] This effort has generally been successful. Russian aircraft have been able to conduct mass glide bomb strikes against Ukrainian defenders on critical sectors of the front because Russian strikes on urban areas fixes high-end air defense systems far to the rear.

The Russian military command likely hoped that a combination of Russian efforts to fix Ukraine's air defense in the rear and increasing Ukrainian air defense missile shortages in Spring 2024 would eventually permit Russian forces to conduct large-scale aviation operations to bomb rear Ukrainian logistics and cities to devastating effect, but the resumption of US aid in Summer 2024 prevented this from happening.[63] Russian pressures on Ukraine's air defense umbrella have also allowed Russian forces to widely conduct fixed-wing drone reconnaissance deep in the Ukrainian rear to optimize Russia's TRSC and improve the accuracy of the missile and drone strike campaign.[64] Ukrainian officials have indicated that Ukraine aims to restore Ukraine's ability to effectively operate in the air domain, and Ukrainian forces would likely have to place similar pressures on Russia's air defense umbrella to do so.[65]

Long-range strike campaigns will place pressures on air defense umbrellas near Taiwan and along the first island chain in the event of PRC aggression against Taiwan and will impact how freely belligerents can operate aircraft and conduct reconnaissance in certain areas. The PRC can choose to prioritize strikes against targets in certain areas that are lower-priority for its own operations but very important for Taiwan and its partners to defend in order to create zones of reduced air defense coverage in designated attack sectors. Defenders must evaluate their air/missile defense requirements with an understanding that they will likely have to allocate more assets to the defense of top-priority economic and political targets than those targets would merit in a strictly military

sense and must therefore have enough high-end air defense assets to do so while also adequately covering likely military operational sectors.

Taiwan may be susceptible to similar pressures despite its much smaller size. Air/missile defense systems like the Patriot cannot make the best use of their long ranges when in missile-defense mode. The requirement to defend Taipei from ballistic missiles, therefore, could lead to the necessity to concentrate multiple Patriot batteries in its near vicinity that could give coverage to the capital and its immediate environs but would not be able to cover Kaohsiung and the south, more than 300 kilometers away. A PLA invasion plan that prioritizes threatening Taipei but actually landing in the south, possibly using the Penghu archipelago as a forward concentration area, could force Taiwan to make difficult choices similar to those facing Ukraine despite the island's relatively small size.

Taiwan's partners will very likely face such trade-offs when considering the defense of the Japanese archipelago and the Philippines. Major military bases such as Okinawa and the Japanese home islands themselves must be defended against PLA missiles, and that requirement could expose Japanese islands closer to Taiwan to PLA air and missile attack, potentially undermining the ability of Japan and the US to use those islands actively for Taiwan's defense. The US can partially offset this challenge by using the missile-defense systems aboard its naval vessels, as it has done in the case of the two major Iranian strikes on Israel, although it must then also be able to keep those ships alive.

Lessons from Ukraine for Maritime Interdiction Efforts in the Taiwan Strait and the Indo-Pacific

Ukraine has conducted a successful maritime interdiction effort against the Russian Black Sea Fleet (BSF) since Summer 2023, demonstrating that countries with few or no conventional naval capabilities can inflict defeats on countries with superior navies. The Russian BSF pursued two major campaigns from the outset of the full-scale invasion: launching Kalibr missiles from surface ships and submarines as part of Russia's strike campaigns and imposing an undeclared but de facto blockade of Ukraine's last major remaining port to stop Ukraine from exporting grain and other goods by sea. The Ukrainian navy had never been large, and the elements that survived the 2014 Russian invasion of Crimea had withdrawn largely to the port of Mykolayiv, which Russian forces attacked and nearly took in early 2022, effectively eliminating the remnants of the Ukrainian fleet. Ukraine thus had to find other ways to disrupt the Russian BSF's strike campaign and blockade, and it did so through a combination of air and naval drones and long-range missiles.

Ukraine's maritime interdiction effort initially aimed to force the BSF to move ships away from its main base in occupied Sevastopol, Crimea and hamper the BSF's ability to interfere with maritime trade in the western Black Sea.[66] Ukraine was able to achieve these goals and effectively push the BSF out of the western Black Sea not through directly controlling naval areas but by targeting the capabilities that Russia would need to

maintain its military posture in the western Black Sea. Ukraine destroyed or heavily damaged at least a third of the BSF vessels deployed in the Black Sea through naval drone strikes and mixed drone and missile strikes.[67] Ukraine continues its maritime interdiction effort against the BSF, likely aiming to destroy Russia's ability to exert pressure and maintain logistics in the Black Sea entirely by expanding its strike efforts to the remaining Russian port of Novorossiysk in the eastern Black Sea. Ukrainian maritime drones have the ranges needed to strike Russian vessels there (600-700 kilometers), but they have not yet resolved certain tactical problems posed by Russian defensive responses considered below.

Ukraine has conducted several successful strikes leveraging drones and long-range missiles against major and minor Russian surface combatants in port and at sea in and around occupied Crimea. Ukrainian forces conducted the first successful naval drone strike against the Russian navy in early August 2023 when they severely damaged the *Olenegorsky Gornyak* Ropucha-class landing ship in Novorossiysk and proceeded to damage and destroy over 20 Russian naval vessels with naval drones at ports and in open waters in the Black Sea.[68] The naval drones ostensibly should not be able to destroy major surface combatants given their small payloads but have been able to do so because of the ability of Ukrainian operators to achieve incredibly precise strikes against vulnerable points on Russian vessels. The BSF appeared to be unprepared to repel Ukrainian naval drones when Ukrainian forces began using them in Summer 2023 but has improved its ability to defend against such strikes by relying on naval aviation, particularly rotary-wing aircraft to identify and destroy maritime drones.[69] Ukrainian forces have also struck many BSF assets in port with long-range missiles — for example, Ukraine used Western-provided long-range missiles to damage the same Kilo class submarine twice in occupied Sevastopol in September 2023 and August 2024.[70] Ukraine has conducted many combined aerial drone, naval drone, and missile strikes against BSF assets in port, and these strikes have sought to overwhelm Russian air defenses and strike several targets at once. Ukraine also conducted strikes that damaged port facilities, including crucial shipyards and repair facilities, to degrade the BSF's ability to continue to operate out of ports in occupied Crimea.[71] Ukraine's notable sinking of the *Moskva, the* BSF's flagship cruiser, earlier in April 2022 is a notable departure from the maritime interdiction effort that would follow in Summer 2023, since Ukraine used two Neptune anti-ship missile to sink the Moskva while it was in open water in the western Black Sea.[72]

It is easy to dismiss Ukrainian successes against the BSF as the result of Russian incompetence or poor technology, and, indeed, examinations of the circumstances of the sinking of the *Moskva* show multiple Russian failures that a more professional navy would likely have avoided. But Ukrainian air and naval drone and missile attacks have also been successful against better-defended and more professionally-handled Russian ships fully on alert for such strikes. The offense-defense race visible on land is also in play at sea, and modern navies, including the PLAN, will remain vulnerable to combined air-sea drone and missile campaigns when the attacking force can manifest a temporary technological or tactical advantage or take advantage of the inevitable mistakes even the best militaries make.

Russia's need to defend certain facilities in and around Crimea has let Ukrainian forces conduct repeated strikes to reconnoiter and test Russian air/missile defenses to find ways of penetrating them. Ukrainian forces have routinely targeted the BSF's former main base in occupied Sevastopol, BSF support infrastructure elsewhere in occupied Crimea, and the BSF's current main base in Novorossiysk, Krasnodar Krai.[73] The Russians must defend these positions, and so must continue to replace damaged or destroyed air/missile defense systems and reinforce those systems when they fail. These repeated strikes allowed Ukrainian forces to thoroughly test the Russian air defense umbrella protecting BSF assets and plan strikes that effectively penetrated those air defenses. Consistent Ukrainian strikes made maintaining a significant naval presence with the associated support and logistics infrastructure in Sevastopol increasingly difficult and pressured the Russian military to redeploy those assets to Novorossiysk. The constrained and vulnerable Russian ground and sea lines of communication (GLOCs/SLOCs) between Krasnodar Krai and occupied Crimea added further pressure on Russia's ability to maintain a significant naval presence in Sevastopol, and the Russian military command eventually redeployed the majority of BSF assets to Novorossiysk by Winter 2023-2024.[74]

The fact that there are only two ports capable of supporting significant elements of the BSF in the Black Sea facilitated the Ukrainian maritime interdiction effort's ability to effectively force a decision point on the BSF. The PRC has many more ports, to be sure, some of which are out of range of plausible Taiwanese strikes, and does not suffer from the limitations that the Montreux Convention imposes on Russia's ability to bring naval reinforcements from other theaters to bear. But the number of PRC ports suitable for the concentration, dispatch, and support of a massive invasion force is much more limited, and those ports are within range of potential Taiwanese drone/missile operations. The PLAN also suffers from the challenge of having to navigate constricted waters for some distance after leaving certain key harbors, whereas Sevastopol and Novorossiysk have more straightforward access to open ocean.

There will be other important differences between Ukraine's maritime interdiction effort in the Black Sea and maritime interdiction efforts at scale in the Taiwan Strait and the western Pacific. Maritime interdiction efforts in the Black Sea have been one-sided, with Ukrainian unmanned systems attacking Russian ships and air defense systems while Ukraine has had no ships of its own to defend. The PRC and Taiwan and its partners will have to both conduct maritime interdiction efforts of their own and defend their own vessels against them, further complicating the assets, capabilities, and naval posture that belligerents in the Indo-Pacific will need. Taiwan will have to attempt to protect its own crewed ships from PLA attacks of all sorts, including maritime and air drones. These mutual interdiction and protection efforts will also occur in a much more compressed area than has been the case in the Black Sea, presenting problems of traffic control unknown to the Russia-Ukraine conflict at sea thus far.

Ukraine has also benefited from the fact that it has faced no meaningful threat of amphibious attack since the early days of the war and so has been able to choose the times and places of its attack. Ukrainian forces have not been expected to target specific naval assets at specific times to disrupt specific naval operations and likely could not have done

so successfully. Maritime interdiction efforts associated with PRC aggression against Taiwan will accompany multiple phases of naval operations, and maritime interdiction efforts in the lead up to, during, and after a PLA landing operation will likely have different priority target sets. The challenge of striking a force at a known time and location that is most likely on highest alert for such an attack and has concentrated all available defensive assets is considerably more complex than the challenge that has faced Ukraine thus far. Taiwan and its partners, on the other hand, have conventional means of attacking maritime forces orders of magnitude greater in number and capability than those Ukraine has ever possessed. A Taiwanese maritime and air drone campaign against the PLAN will almost certainly be an auxiliary effort to a more conventional maritime defensive operation, therefore.

Scaling up the Ukrainian approach to the maritime interdiction effort will likely require some significant changes and presents opportunities for new adaptations. Both the distances and the far larger navies involved in a potential war in the Indo-Pacific will require maritime interdiction efforts at a far larger scale. This scale will likely incentivize several new approaches not seen in the Black Sea. Ukraine has so far fielded naval drones in limited numbers and primarily for strike purposes, but belligerents in the Indo-Pacific will likely be incentivized to field naval drones in far greater numbers and rely more heavily on naval drones for reconnaissance functions. There have yet to be instances of mass naval drone strikes in the Black Sea, and the ability of naval vessels to respond to such strikes is thus unclear. Belligerents in the Black Sea have yet to field submersible naval drones at scale, and belligerents in the Indo-Pacific may be more incentivized to field such capabilities in efforts to cause more damage to a greater number of major surface combatants. Maritime interdiction efforts in the Indo-Pacific will require coordinating combined aerial and naval drone and missile strikes at greater distances from distant separate locations but will also allow belligerents to experiment with flight and sea paths to test their adversary's response in ways similar to how Ukrainian and Russian forces experiment with flight paths in their long-range strike campaigns. The scale of naval operations in the Indo-Pacific will likely reduce the requirement to rely solely on long-range precision strikes to conduct effective maritime interdiction efforts, however, and ISW offers the concept of the Tactical-Reconnaissance Strike Complex (TRSC) as a framework for organizing more pervasive strike and reconnaissance elements in support of a maritime interdiction campaign.

The Tactical-Reconnaissance Strike Complex (TRSC) seen in Ukraine's land war is not a concept exclusive to ground warfare, and recreating the TRSC at sea may allow belligerents in the Indo-Pacific to conduct effective, pervasive, and consistent maritime interdiction efforts. Militaries can use the same types of drones seen throughout the frontline in Ukraine to conduct pervasive tactical reconnaissance at sea while also correcting short-range fires from surface combatants. Belligerents at sea can use both unmanned aerial vehicles (UAVs) and unmanned surface vehicles (USVs) as extensive short-range fires to achieve the same area and maneuver denial that cheap FPV drones achieve on the battlefield in Ukraine. Just as Ukrainian and Russian forces leverage pervasive tactical reconnaissance to conduct long-range strikes for tactical effects, there is no reason why belligerents cannot integrate tactical drone-based reconnaissance into long-range precision strikes against naval targets at sea.

Russian and Ukrainian forces have leveraged their TRSCs to constrain their adversaries' maneuver and to support offensive operations of their own, and the pervasiveness of the TRSC and its ability to rapidly develop and withstand shocks and temporary degradation has been a major contributing factor to positional warfare in Ukraine. Positional warfare as well is not a concept relegated only to ground warfare, as belligerents can establish roughly continuous lines along various land formations at sea and interfere with adversary ships attempting to sail past those points.[75] It is in Taiwan's and its partners' interest to deny PLAN maneuver in the Taiwan Strait and around Taiwan as quickly as possible and create the conditions of a positional naval front that prevents the PLA from being able to conduct a landing operation. The TRSC provides opportunities for achieving these effects.

The fact that current land-based aerial drones are largely unable to sink large ships on their own does not render them useless in maritime conflict. Ukraine and Russia have used cheap drones as a pervasive strike and fire element along the entire frontline to damage high-end systems and prevent the adversary from achieving combat tasks and missions, and both aerial and naval drones can achieve parallel effects at sea.

Attack drones in Ukraine generally seek to achieve kills or mission kills either by placing their own limited payloads precisely on known vulnerable points of enemy systems or by dropping or launching purpose-built munitions such as shaped-charge rounds against relatively vulnerable areas—the tops of tank turrets, for example. Drone attacks in Ukraine are more likely to achieve mission kills—inflicting enough damage to prevent the target from continuing to execute its mission but not enough to prevent it from being subsequently repaired if it can be recovered in time—than system kills. Mission kills are sufficient to stop armored attacks at scale, however, as Ukraine has repeatedly demonstrated. The fact that the Russians are often able to recover damaged vehicles and repair them does not alter the reality that the attacks those vehicles had been conducting failed.

Belligerents in the Indo-Pacific could leverage drones as tactical fires to achieve mission kills against minor and major surface combatants and similarly destroy those surface combatants at a later date with long-range strike capabilities if necessary. The timing required for a successful amphibious invasion makes such an effort particularly vulnerable to a large number of mission kills—the fact that many such PLAN ships could be repaired at a later date would not offset the disruption to the careful planning required for such an ambitious offensive undertaking.

Belligerents in the Indo-Pacific can achieve mission kills against surface combatants with aerial and naval drones by targeting communication and ISR systems on board the vessels that are critical for their ability to complete assigned missions. Belligerents could use drones to target more specific capabilities on board surface combatants, such as air defense systems or missile launchers, or specific naval capabilities, such as temporarily disrupting the ability to launch naval aviation from aircraft carriers. Such attacks could create vulnerabilities that more conventional anti-shipping systems could take advantage of. Both aerial and maritime drones in the western Pacific will also likely be given the ability to fire more advanced anti-shipping munitions of their own including torpedoes

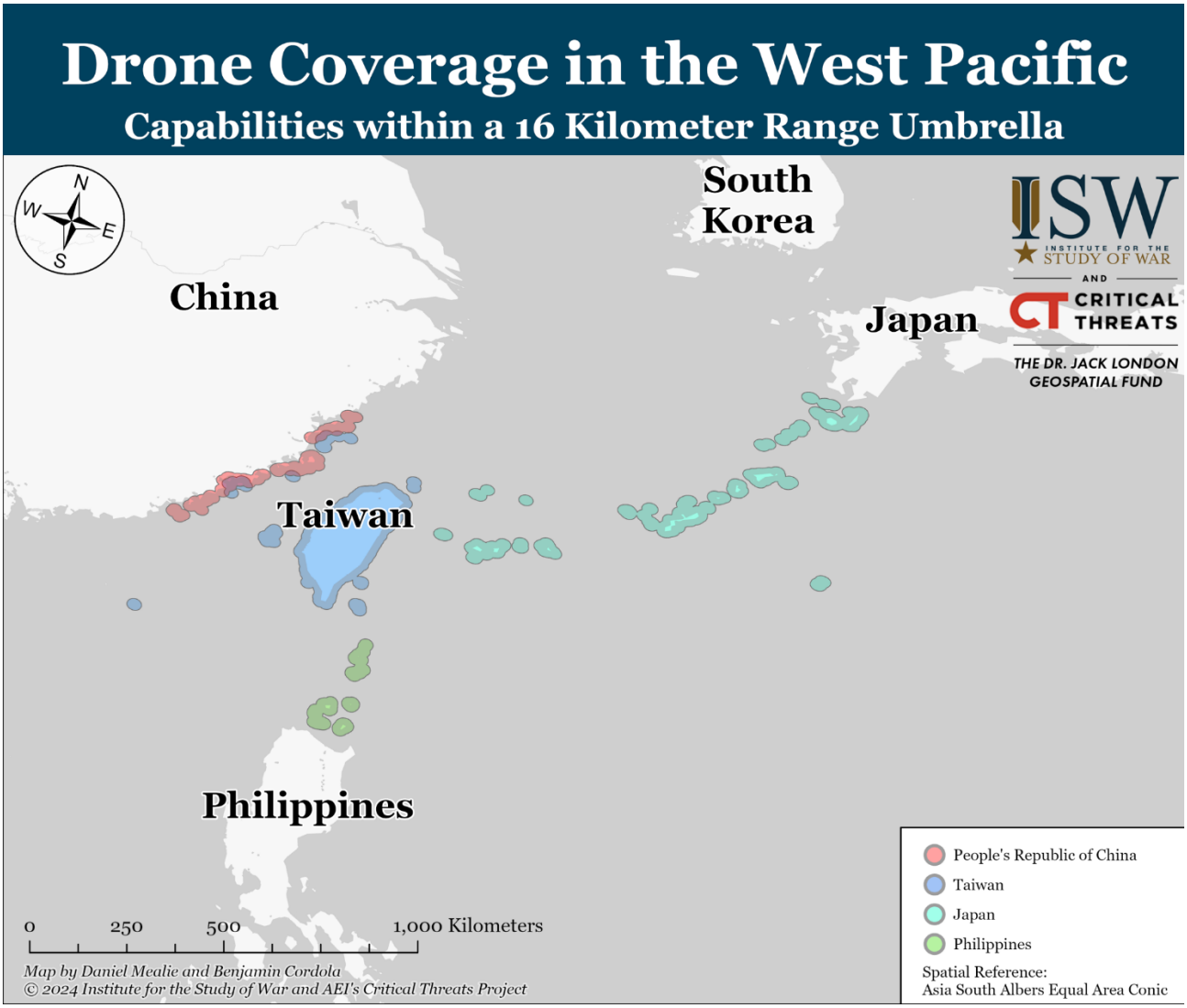
and anti-shipping missiles. The drones required for such munitions will generally be larger and more expensive than those Ukraine has been using the Black Sea, but they will still very likely benefit enormously from clouds of much cheaper reconnaissance and attack aerial and maritime drones.

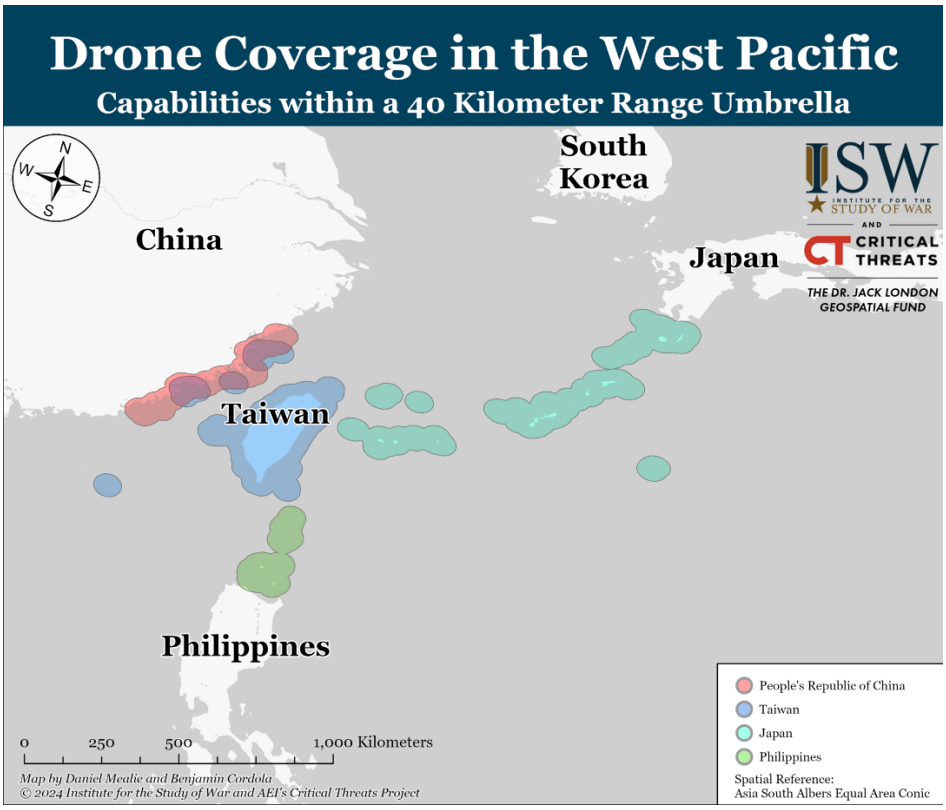
Cheap unmanned systems can likely recreate the pervasive reconnaissance to support fire and strike elements in the Taiwan Strait and the wider Indo-Pacific that they have created in Ukraine. Pervasive drone-based ISR capabilities along the frontline in Ukraine create almost complete visual- and sensor-based transparency on the battlefield.[76] Russian and Ukrainian forces have demonstrated that these ISR capabilities do not eliminate surprise entirely, however, with both sides leveraging ambiguity around operational intent and the novel, temporary benefits of newly fielded innovations to achieve surprise.[77] These efforts to achieve surprise have thus far been occasional, and visual- and sensor-based transparency typically prevents belligerents from achieving surprise along the frontline in Ukraine.

Russian and Ukrainian forces field higher-end long-range reconnaissance drones, but do not have these systems in the quantities needed to establish the pervasive visual- and sensor-based transparency along the roughly 1,000-kilometer frontline in Ukraine. Cheap drones have allowed Russian and Ukrainian forces to acquire the mass needed to field both enough drones to establish such visual- and sensor-based transparency and the stock required to consistently replace the large number of downed tactical drones to maintain ISR capabilities. Belligerents in the Indo-Pacific will not be able to establish the ISR capabilities that form the backbone of the TRSC with their higher-end reconnaissance drones alone and will need to similarly acquire relatively cheap drones en masse to prepare for maintaining visual- and sensor-based transparency in even limited areas in the Taiwan Strait and along the first island chain. Russian and Ukrainian forces use some drones solely as reconnaissance drones, flagging targets for artillery, aviation, missile units, and other drone operators to strike, but most drones can fulfill reconnaissance tasks and then switch to the being the fire element for the target that they have identified. Achieving consistent pervasive ISR capabilities at scale in the Indo-Pacific will likely require drones numbering in the millions, as in Ukraine, and Taiwan and its partners may have to prioritize where to establish routine visual- and sensor-based transparency for maritime interdiction efforts.

The extent of the Taiwanese and Japanese archipelagos offsets the relatively limited range of inexpensive drones. Ukrainian and Russian forces now routinely use large quadcopter drones with ranges up to 40-50 km that can be produced for $25-$50 thousand dollars each. The following map shows the coverage such drones could provide if stationed on the appropriate islands in the Taiwanese and Japanese archipelagos—coverage that extends from the Taiwanese mainland to Kyushu with only one significant gap. Fleets of such inexpensive drones could provide continuous coverage of nearly the entire first island chain and the ability to begin striking vulnerable points of enemy ships they find immediately while transmitting real-time targeting data to more advanced conventional kill systems as well as to maritime drones that can also be based on the same islands and have a much higher probability of inflicting mission kills or even more severe damage. These drones will be susceptible to adversary electronic warfare, of

course, and the offense-defense race will be as intense and rapid in the Pacific as it is in Ukraine. But the side that can adapt more rapidly can gain significant advantages in that race.




Drone Coverage in the West Pacific
Capabilities within a 40 Kilometer Range Umbrella
South Korea
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Japan
Taiwan
Philippines
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THE DR. JACK LONDON GEOSPATIAL FUND
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Map by Daniel Mealie and Benjamin Cordola
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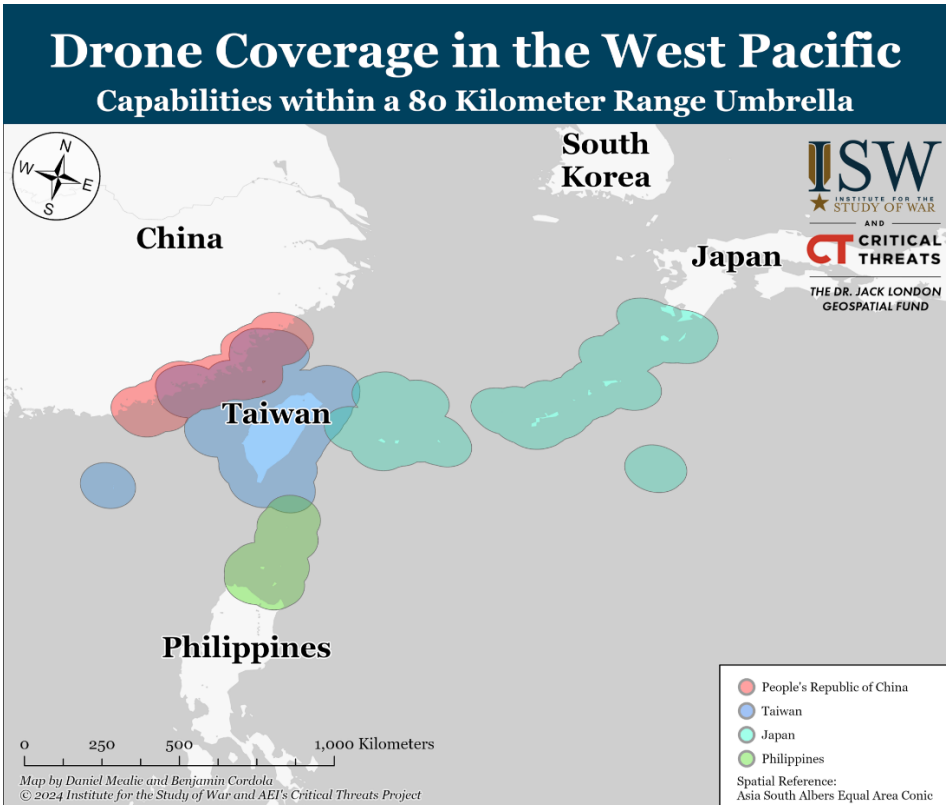
Drone Coverage in the West Pacific
Capabilities within a 80 Kilometer Range Umbrella
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Taiwan
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0 250 500 1,000 Kilometers
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The TRSC in Ukraine is highly decentralized but a TRSC in the Indo-Pacific will likely need to be more centralized. Russian and Ukrainian units as small as companies operate reconnaissance and strike drones and have the authority to prosecute identified targets with their systems and have permission to interact with nearby fire elements to conduct a rapid reconnaissance-strike cycle.[78] Neither Russian nor Ukrainian forces have established an overarching system for coordinating this reconnaissance-strike cycle across the entire frontline, despite Ukrainian efforts to organize target identification and strikes in new innovative battle management systems.[79] Russian and Ukrainian drone operators each individually operate a single drone and neither side has yet started to field drone swarms in which a single drone operator controls a group of drones working in tandem.[80] The current approach to drone operations in Ukraine prioritizes radical decentralization that allows thousands of drone operators to identify and attack targets on their own, although drone operations will likely become more centralized as the war in Ukraine continues.

Drone operations in the western Pacific are more likely to require greater centralization to achieve maximum effect. Individual drones can execute mission kills or total kills against armored vehicles, tactical positions, aircraft, and other targets in Ukraine. But individual small drones are extremely unlikely to generate similar effects on ships. Achieving mission kills or catastrophic damage against ships will almost certainly require the complex interaction of many small drones, larger drones, and conventional systems. That interaction, in turn, will require a much higher degree of centralization than has been observed on either side in Ukraine. That centralization poses a challenge in that it means that drones in the western Pacific will have to continue to be able to communicate with one another and with their operators, whereas drones in Ukraine are increasingly evolving toward autonomous systems that can function without any external communications due to the intense EW environment.

Heavy electronic warfare (EW) contested environments that achieve area denial and degrade an adversary's communications and TRSC are not confined to ground warfare. Extensive offensive and defensive EW assets support efforts in Ukraine to maintain an effective TRSC while degrading the adversary's TRSC.[81] Russian and Ukrainian forces heavily rely on EW to create area denial for drones and to limit the ranges that enemy drones can effectively operate into the rear, presenting opportunities for degrading the pervasive reconnaissance and fire support that drones offer the TRSC.[82] EW and drones are heavily linked technologies in the offense-defense race in Ukraine and will likely continue to be so in future wars. EW capabilities that degrade drone operations and communications can significantly constrain an adversary's offensive capabilities, as seen with Russia's effective use of the TRSC to degrade communications and drone operations at the start of the Ukrainian Summer 2023 counteroffensive.[83] EW can also affect fire and strike components of the TRSC as seen with Russia's ability to jam Ukrainian GPS-guided precision weapons during Ukrainian interdiction efforts in the lead up to and during the Summer 2023 counteroffensive.[84] EW operations will constrain where and how belligerents in the Indo-Pacific can use drones, communications, and strike and fire elements, and it is likely that belligerents will concentrate EW systems close to minor and major surface combatants in the event that drones play a prominent role in maritime interdiction efforts. EW operations that create

extensive area denial at sea could create routes for naval maneuver that the TRSC seeks to constrain, and Taiwan and its partners should be prepared to degrade and penetrate PLA EW coverage.

Satellite communications, now available for large quadcopters as well as for maritime drones, have significantly offset the EW challenge in Ukraine for now, although the Russians have fielded systems that can interfere with Starlink communications in some areas. More advanced military-grade satellite communications systems will likely be harder to disrupt, although PRC anti-satellite capabilities will come into play that the Russians have not yet either developed or deployed.

There will likely be several different options for deploying and operating drones in the Indo-Pacific that will affect the character of drone operations. Russian and Ukrainian forces create drone deployment points as a part of their pre-existing logistics systems for ground operations in Ukraine, and drone operators act as any other tactical fire support element along the frontline. The theater in the Indo-Pacific will offer several notably different options for where and how to deploy and conduct drone operations:

1. *Large island-based drone seeding* — storing, deploying, and operating drones from large islands such as Taiwan, Okinawa, Penghu, and other more significant islands along the first island chain;
2. *Drone seeding on Taiwanese islands near the PRC shoreline* — storing, deploying, and operating drones from Kinmen, Matsu, and other Taiwanese islands very close to the PRC and distant from Taiwan;
3. *Small island-based drone seeding* — supplying, storing, deploying, and operating drones from smaller islands with limited infrastructure such as Taiwan's outlying islands, Yonaguni Island, and other small islands in the Japanese archipelago; and
4. *Naval-based drone seeding* — supplying, storing, deploying, and operating drones from minor and major surface combatants.

Large island-based drone seeding offers more extensive logistics, storage points, and hardened facilities for conducting drone operations, although there are few such islands available, and they do not provide necessary coverage for small drones of current ranges. These larger islands are also priorities for defense, so drone seeding on them is more likely to focus on creating a layered drone-assisted defense-in-depth of the islands themselves in addition to serving as anchor points for drone seeding on smaller islands and ships. The PLA is less likely to be able to field extensive EW coverage deep into Taiwan or elsewhere along the first island chain than in areas closer to PLAN vessels or mainland China. Large island-based drone seeding will therefore likely offer some of the most EW-resistant and least EW-affected areas for conducting drone operations at least until PLA or PLAN forces near them or land.

The Taiwanese islands of Kinmen and Matsu offer prime locations for extensive drone basing that could severely hamper PLA concentrations, PLAN preparations and loading,

and PLAAF operations. The PRC is no doubt aware of this risk, however, and is able not only to concentrate intensive EW on those islands but also to attack them with a wide variety of land-based systems. The short range from the mainland to Kinmen in particular could mean that a defense of Kinmen might look more similar to the sort of drone-enabled operations seen in Ukraine than any undertaking in a Taiwan conflict scenario other than an actual invasion of Taiwan. Taiwan and its partners would likely need to move swiftly to get an effective TRSC in place on Kinmen well in advance of conflict, as disrupting the development of such a capability would likely be a high priority for the PLA.

Small island-based drone seeding offers opportunities for inexpensively contesting large areas of the ocean and presenting the PRC with a knotty dilemma in having to locate and suppress drones operating from many small islands, often with various forms of good concealment. Small islands, on the other hand, will have fewer and smaller storage facilities and will require resupply to conduct consistent drone operations over a long period.

Naval-based drone seeding offers even greater opportunities for conducting drone operations in support of maritime interdiction efforts but faces various challenges and limitations including storage and resupply constraints as well as the requirement to keep the ships operating the drones alive. Naval-based drone seeding also offers opportunities for drone operators to have close communications with fire elements on board the same surface combatant and for the surface combatant to coordinate combat tasks alongside drone operations. Naval-based drone seeding will also allow for more maneuverable drone operations at sea and may allow belligerents to more rapidly use drone operations to exploit adversary vulnerabilities.

The PLA will likely field a TRSC with many of the capabilities seen in Ukraine, and degrading the PLA's TRSC will likely be a critical effort supporting a maritime interdiction campaign. The PRC has been paying attention to lessons from the war in Ukraine, although it remains unclear what lessons exactly it is drawing upon or internalizing. The PLA's "intelligent warfare" concept prioritizes artificial intelligence (AI) and autonomy and is also prompting the PLA to focus on drone operations of a certain sort, but it could also support PLA efforts to borrow from the concept of the TRSC as well.[85] Both Russian and Ukrainian forces leverage components of their TRSC to degrade their adversary's TRSC in an effort to gain capability advantage and make territorial advances in select tactical areas before the adversary quickly restores capability parity in the area.[86] Russian and Ukrainian forces widely use EW to this effect, have made counterbattery missions a key component of weakening the adversary's TRSC, and are rapidly fielding new drone-on-drone interception capabilities to degrade drone-based elements of the TRSC.[87] Efforts to degrade the PLA's TRSC and protect the TRSCs of Taiwan and its partners will directly impact the effectiveness of maritime interdiction efforts and should be thought of as a parallel effort to the maritime interdiction campaign.

All fielded drone and EW systems in Ukraine do not have equal capabilities and are not equally dispersed, and this phenomenon will be especially true across the wider Indo-Pacific. These disparities will generate areas vulnerable to successful maritime interdiction efforts and place a premium

on being able to quickly identify and exploit such areas. The decentralized nature of drone operations in Ukraine generates inconsistencies in drone capabilities across the frontline, with Ukrainian and Russian forces on some sectors of the front having access to integrated battle management systems and extensive drone stocks that allow them to use several drones against one target while Russian and Ukrainian forces on other sectors have far more limited capabilities. Russian and Ukrainian forces along the front generally have consistent access to basic EW systems, but higher-end and more effective EW systems are more limited and concentrated. The EW systems that Russian and Ukrainian forces operate also overheat after extended use and therefore cannot generate constant continuous EW coverage, although the PRC and Taiwan and its potential partners may be able to field more exquisite EW systems that could achieve such constant and continuous coverage. Ukraine's recent incursion into Kursk Oblast in early August 6 resulted in rapid Ukrainian gains in part because Ukrainian forces attacked in an area where Russian forces had not established significant TRSC or EW coverage — showing that rapid maneuver is possible when one identifies and exploits an area where the adversary has poor TRSC and EW coverage.[88]

Disparities in fielded drone and EW systems in the Indo-Pacific will create areas with more effective and less effective TRSC, and this will heavily influence belligerents' ability to field TRSC capabilities of their own and conduct effective maneuver. The indicators for where an adversary has stronger, weaker, or even no TRSC coverage may not be readily apparent, and it is likely that differences in TRSC coverage will change dynamically and possibly rapidly. Quickly identifying and exploiting areas with weaker or no TRSC coverage will be one of the most effective ways to conduct successful maritime operations in conditions in which belligerents field extensive TRSC capabilities to support maritime interdiction efforts.

A pervasive TRSC that allows Taiwan and its partners to conduct a continuous and effective maritime interdiction campaign against the PRC may allow Taiwan to establish a defense in depth that would otherwise be impossible to achieve. Defense in depth requires a layered series of defenses that can delay, disrupt, and degrade an adversary as he attempts to advance, but Taiwan lacks the space on land to establish such depth, and there will be few opportunities to delay, disrupt, and degrade the PLA once PLA forces have landed on the island of Taiwan. Extensive TRSC coverage could create layers of defense in the Taiwan Strait that the PLAN would have to break through before conducting a landing operation and assaulting Taiwan's land defenses. A TRSC that effectively constrains PLAN maneuver would likely delay, disrupt, and degrade the capabilities that the PLA aims to leverage to conduct a landing operation against Taiwan. Taiwan and its partners' ability to field such an effective TRSC depends on many unclear factors, including:

1. Can Taiwan and its partners acquire the quantity of aerial and naval drones needed to immediately field a TRSC at the start of PRC aggression? Are Taiwan and its partners able and willing to scale the production of drones, EW, and other materiel quickly enough to support the requirements of a consistent and pervasive TRSC?

2. Can Taiwan and its partners pre-position the constituent elements of the TRSC in order to start leveraging the TRSC to immediately constrain PLAN naval maneuver?
3. How effective will the PLA's TRSC be and what EW capabilities is the PLA prepared to field in its aggression against Taiwan?
4. Can mass PLAN naval maneuver overwhelm the TRSC that Taiwan and its partners establish? How large would such maneuver have to be to start degrading the TRSC's ability to restrain maneuver?
5. Will the elongated SLOCs of Taiwan's partners significantly impact the ability to field new drone, EW, and other adaptations at the pace at which the TRSC and innovation cycle develops in a war with the PRC?

Taiwanese strategy with Ukrainian insights

Applying lessons from Ukraine to Taiwan's approach to long-range strike campaigns and maritime interdiction efforts will empower Taiwan to develop a strategy for defending against PRC aggression. ISW offers these lessons from Ukraine to inform Taiwanese and partner strategy about organizing a defense against PRC aggression and not as the strategy itself. Protracting and diminishing the effectiveness of the PLA long-range strike campaign and conducting a successful maritime interdiction effort that constrains and slows PLAN naval maneuver are two operational courses of action that may offer Taiwan the opportunity to delay, disrupt, and degrade the PLA's offensive plans and capabilities. Taiwan and its partners should think hard about how these opportunities can be integrated into a wider coalition strategy in which Taiwan's partners can apply their greater capabilities to Taiwan's defense after leveraging the delays, disruptions, and degradations that Taiwan inflicts against the PLA.

Many expected Ukraine to succumb to Russian aggression at the outset of the full-scale invasion, and Ukraine's resistance offers Taiwan a blueprint for a scenario in which a democratic state with the backing of the West surprises experts by avoiding destruction by a much larger totalitarian state embarked on a war of unprompted aggression. Ukraine has shown tremendous aptitude to innovate to offset Russian materiel and manpower advantages and resilience in attempts to break out of parity and restore maneuver to liberate Ukrainian territory. Ukraine has effectively followed a strategy to minimize costs while inflicting asymmetric losses on Russian forces. Taiwan, with likely greater backing from Western partners than Ukraine has received, can demonstrate the same aptitude for innovation and the same resilience for maintaining costs and advantages over the PRC. Taiwan must commit itself to a resistance like Ukraine's, but with Taiwanese characteristics, if it is to survive aggression by the PRC.

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