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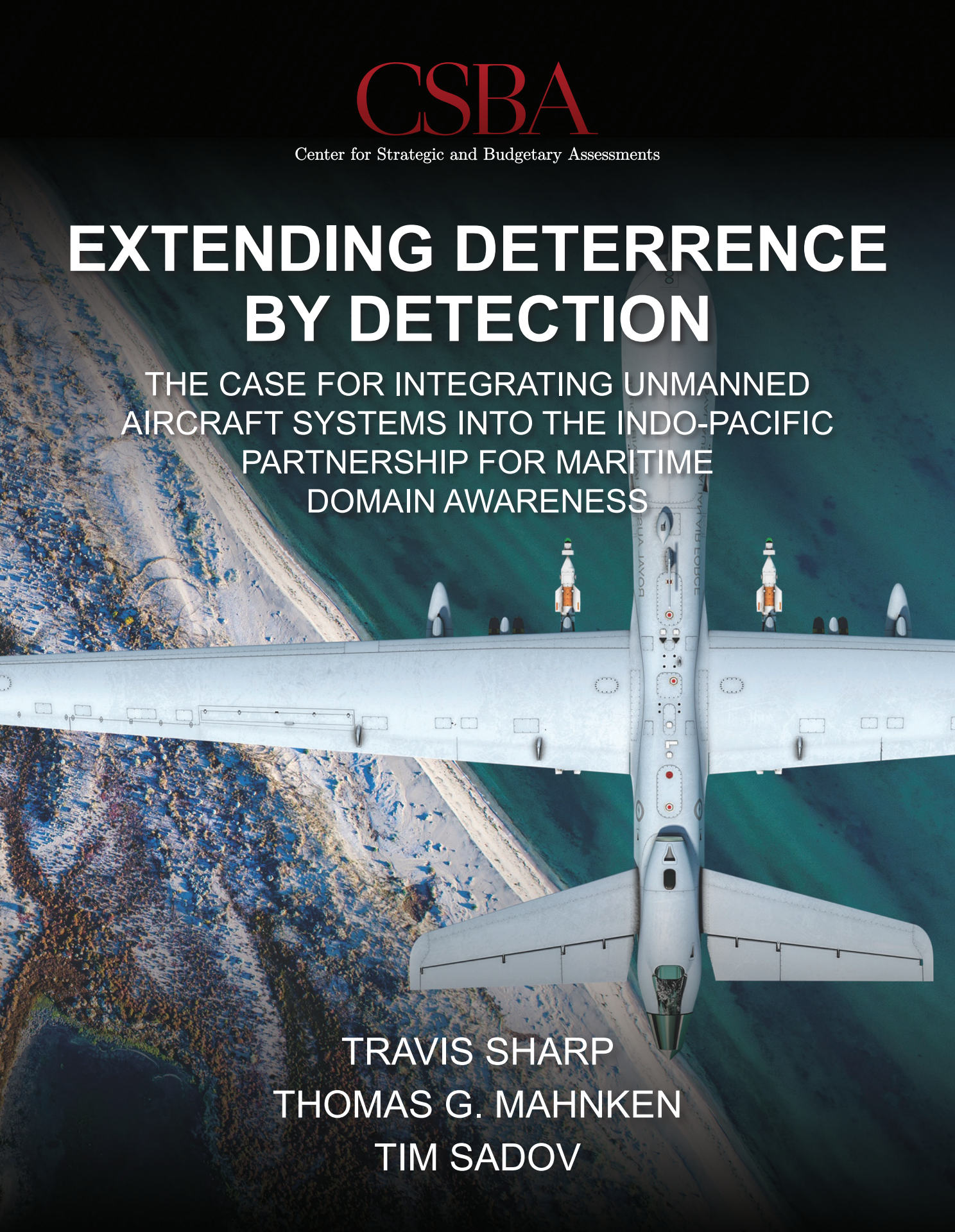
# EXTENDING DETERRENCE BY DETECTION

## THE CASE FOR INTEGRATING UNMANNED AIRCRAFT SYSTEMS INTO THE INDO-PACIFIC PARTNERSHIP FOR MARITIME DOMAIN AWARENESS

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## ABOUT THE CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS (CSBA)

The Center for Strategic and Budgetary Assessments is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

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# Executive Summary

Over the past year, developments in Washington and the Indo-Pacific region demonstrated the growing multinational commitment to using existing intelligence, surveillance, and reconnaissance (ISR) capabilities to monitor and discourage antagonistic maritime activities, including by China. Most significantly, in May 2022, the "Quad" nations — the United States, Australia, Japan, and India — announced the creation of the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA) to monitor illegal fishing, humanitarian crises, maritime security, marine conservation, and related issues in the region.[1]

IPMDA's most significant activity involves disseminating unclassified data collected by commercial satellites to improve the common operating picture of participating nations and bolster information sharing across regional fusion centers, including in India, Singapore, the Solomon Islands, and Vanuatu.[2] The Quad pledged to support IPMDA through funding, training, consultations, and technology.

Most expert commentary on IPMDA in the United States and allied nations has consisted of general praise echoing official governmental statements. This report offers a sharper critique in the hope of strengthening IPMDA, a promising initiative aligning with CSBA's "Deterrence by Detection" ISR operational concept described in studies published in 2020

1 White House, "Quad Joint Leaders' Statement," May 24, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/24/quad-joint-leaders-statement/.

2 White House, "Background Press Call Previewing President Biden's Final Day in Japan," May 23, 2022, https://www.whitehouse.gov/briefing-room/press-briefings/2022/05/23/background-press-call-previewing-president-bidens-final-day-in-japan/; and White House, "Fact Sheet: Quad Leaders' Tokyo Summit 2022," May 23, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/23/fact-sheet-quad-leaders-tokyo-summit-2022/.

and 2021.[3] The creation of IPMDA provides a vehicle for advancing Deterrence by Detection-style concepts.

After recapping Deterrence by Detection, rebutting its critics, and tracing its growing influence in Washington and beyond, the report advances three arguments about IPMDA based on detailed analysis. First, the Quad has pooled political power in IPMDA that it can convert into military power later if political leaders judge doing so to be in their collective interests. Second, if IPMDA relies solely on commercial space-based collection, it will fall short of meeting Indo-Pacific nations' information needs regarding antagonistic Chinese maritime activity and other regional security threats. Third, furnishing IPMDA with a small fleet of unmanned aircraft systems (UAS), a feasible and affordable option, would improve the initiative's ability to monitor regional hotspots such as the South China Sea.

## Critical Appraisal of IPMDA

IPMDA focuses strictly on law enforcement and maritime safety, but it develops organizational infrastructure and surveillance practices that the Quad can repurpose for military operations later if desired. If pressed, Quad leaders should forthrightly acknowledge IPMDA's military potential, and thereby implicitly threaten its actualization, to avoid the self-defeating contradiction of denying the existence of latent military strength where it so obviously exists.

IPMDA's current emphasis on disseminating commercial space-based collection means that its advantages and disadvantages will reflect those of commercial collection regardless of whether it embraces military objectives. Reviewing those attributes allows us to formulate concrete expectations about IPMDA's performance.

- Advantages: Commercial space-based collection possesses high shareability and growing ubiquity relative to classified government systems, as well as complementarity with those systems. As a result, IPMDA will likely increase information flows across and within participating governments, provide governments with insights on many activities and locations of potential concern, and enable governments to tip and cue their classified intelligence capabilities if they choose to do so.
- Disadvantages: Commercial space-based collection's information security, responsiveness to government needs, and resolution and access generally lag classified government

3 Thomas G. Mahnken, Travis Sharp, and Grace B. Kim, *Deterrence by Detection: A Key Role for Unmanned Aircraft Systems in Great Power Competition* (Washington, DC: Center for Strategic and Budgetary Assessments [CSBA], April 2020), https://csbaonline.org/research/publications/deterrence-by-detection-a-key-role-for-unmanned-aircraft-systems-in-great-power-competition; and Thomas G. Mahnken, Travis Sharp, Christopher Bassler, and Bryan W. Durkee, *Implementing Deterrence by Detection: Innovative Capabilities, Processes, and Organizations for Situational Awareness in the Indo-Pacific Region* (Washington, DC: CSBA, July 2021), https://csbaonline.org/research/publications/implementing-deterrence-by-detection-innovative-capabilities-processes-and-organizations-for-situational-awareness-in-the-indo-pacific-region.

systems for various reasons. As a result, IPMDA will likely face the continuous risk of disruption by China or another actor opposed to its activities, remain vulnerable to pressures placed on the commercial firms supporting it, and fail to enable law enforcement and other operations requiring finer-grained intelligence.

## Integrating Unmanned Aircraft Systems into IPMDA

Furnishing IPMDA with a small UAS fleet would provide more granular and persistent surveillance of important ISR collection areas than commercial space-based collection would achieve on its own. First, UAS provide full motion video and other forms of high-resolution imagery continuously, whereas commercial satellites do not produce video and collect imagery only intermittently based on their revisit rates. Second, UAS equipped with multiple sensors, such as a camera and signals intelligence (SIGINT) pod, can find, fix, and track targets independently by correlating observations across different collection methods in near real-time, something commercial satellites do not do.

Integrating UAS into IPMDA would prove beneficial even if the initiative never adopts military objectives. The report presents a novel operational analysis showcasing how a small UAS fleet would improve IPMDA's surveillance of the South China Sea (SCS), an area of immense importance for regional security. The analysis first divides the SCS into a grid using latitude and longitude lines and assigns each box a weighted value based on assessed ISR collection importance. It then considers IPMDA's base case of commercial satellites collecting broadly but shallowly across the grid with a supplemental option of UAS collecting narrowly but deeply. It examines UAS rather than alternatives such as manned aircraft or naval ships because it focuses on long endurance ISR operations in line with previous Deterrence by Detection studies. Future research could use the same setup to analyze other geographic areas, such as the Indian Ocean region, where India faces a growing challenge from China.

The analysis evaluates a fleet of three UAS in different configurations, varying the basing location (Guam and/or the Philippines), aircraft endurance (40-hour or 80-hour), and collection strategy (broad or targeted). Guam basing exemplifies IPMDA deciding or being forced to operate UAS from a Quad country's territory, whereas Philippines basing represents an SCS littoral nation agreeing to host UAS.

The analysis finds that UAS greatly improve SCS surveillance relative to commercial satellites if the UAS adopt a targeted collection strategy of loitering longer in more important areas. The UAS configuration featuring Philippines-based, 40-hour endurance aircraft performs best according to most criteria, including after normalizing the results per collection hour. This finding reaffirms the commonsense notion that better basing enables better ISR collection in the vast Western Pacific theater. To borrow the saying from real estate, Indo-Pacific ISR aircraft operations are all about location, location, location.

Despite its higher effectiveness, the best performing configuration fails to cover the grid's western half near Vietnam under the preferred targeted collection strategy. The configuration would require 14 aircraft, not the three aircraft used in the analysis, to survey the entire grid in one collection cycle of all aircraft simultaneously flying their full endurances.

The findings carry three implications for integrating UAS into IPMDA.

1. IPMDA's most feasible option combines collection by commercial satellites and UAS. Fielding over a dozen UAS in the Philippines to surveil the entire SCS grid in one collection cycle, as required under the best-performing configuration, likely would prove impractical politically and budgetarily for IPMDA. That is why the report recommends UAS as a supplement, not a replacement, for commercial space-based collection. Combining broad collection by commercial satellites with targeted collection by UAS provides a middle-ground option that should prove both more effective than commercial satellites alone and more feasible than UAS alone. A contractor-owned, contractor-operated fleet of three UAS would cost IPMDA approximately $50 million per year, an expense that could be split among those Quad members willing to contribute.

2. IPMDA would improve its surveillance of the SCS by operating UAS from Vietnam. The failure of the best performing three-aircraft configuration to surveil important areas near Vietnam when conducting targeted collection indicates that Philippines basing is incredibly helpful, but alone insufficient, for maintaining comprehensive maritime domain awareness in the SCS. If fielding over a dozen 40-hour UAS (or multiple 80-hour UAS) in the Philippines proved infeasible for IPMDA, as seems likely, then IPMDA could also base UAS in Vietnam, meaning aircraft would operate from both the Philippines and Vietnam. The most promising Vietnamese bases would include Da Nang in central Vietnam and Nha Trang, Cam Ranh, or Phan Rang in south central Vietnam due to their proximity to important ISR collection areas. Vietnam has a strong incentive to support UAS surveillance by IPMDA given that Vietnam-flagged vessels comprise much of the ship traffic in the SCS.

3. IPMDA would improve its surveillance of both the SCS and adjacent areas by operating long endurance UAS from Japan, Australia, Singapore, or Malaysia. A long endurance ISR aircraft flying from Guam to the SCS crosses a lot of open ocean, limiting the opportunity for collateral collection en route (known as "non-interference basis" or NIB collection). If the Philippines or Vietnam proved unwilling or unable to host UAS, IPMDA would best utilize standoff-based long endurance UAS by operating them from Japan (Honshu), Northern Australia, Singapore, and/or Malaysia. These countries very roughly match Guam's standoff distance from the SCS, but their locations permit SCS-bound aircraft to fly past geopolitically significant areas such as Taiwan and Southeast Asia's maritime chokepoints. UAS operating from the four countries would perform NIB collection while flying to and from the SCS, increasing each sortie's return on investment and delivering valuable collection to countries located outside the SCS. Existing airfields in the four countries offer feasible locations for basing UAS.

CHAPTER 1

# Deterrence by Detection: Recap and Reception in Washington and Beyond

As detailed in CSBA studies published in 2020 and 2021, the Deterrence by Detection operational concept is built on the idea that China and Russia are less likely to commit opportunistic acts of aggression if they know they are being watched constantly and that their actions can be publicized widely.[4] The concept calls for the United States and its allies and partners to maintain real-time, persistent situational awareness in key areas of the Western Pacific and Eastern Europe using existing unmanned all-domain ISR capabilities, particularly non-stealthy UAS possessing longer endurance than manned platforms.[5] The concept recommends boosting the performance of existing ISR capabilities through select technology investments, artificial intelligence-enabled process improvements, and organizational adaptation.

In the Western Pacific, Deterrence by Detection proposes using 46 UAS of various types from existing inventories to surveil the South China Sea, East China Sea, and Taiwan Strait and Chinese coastal areas (**Figure 1**).[6] The estimated operating cost of the 46 UAS would total approximately $700 million to $750 million per year (fiscal year 2023 dollars) based

4 This paragraph synthesizes the original and refined concepts presented in, respectively, Mahnken, Sharp, and Kim, *Deterrence by Detection*, p. 1; and Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, p. 2.

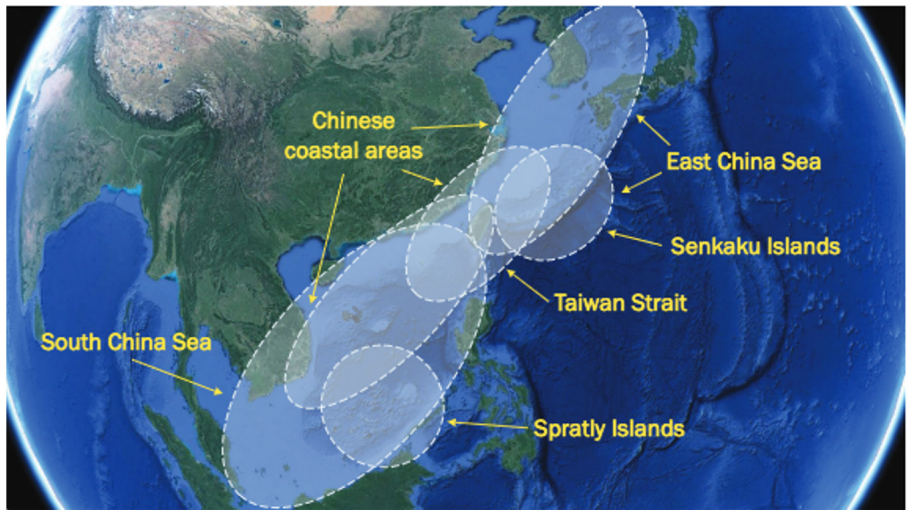
5 An operational concept (or concept of operations) is a verbal or graphic statement that clearly and concisely expresses what the joint force commander intends to accomplish and how it will be done using available resources. Department of Defense (DoD), *DOD Dictionary of Military and Associated Terms*, March 2017, p. 48, https://apps.dtic.mil/sti/pdfs/AD1029823.pdf.

6 Mahnken, Sharp, and Kim, *Deterrence by Detection*, p. 32.

on Congressional Budget Office figures.[7] Since the aircraft would come from existing inventories, not from new purchases, the cost represents money that the United States and its allies and partners would spend anyway to operate the aircraft elsewhere (assuming they continued operating them). As a result, implementing Deterrence by Detection would not require major spending increases. Rather, it would require changing the employment of aircraft already funded in current budgets by redirecting them away from lower priority missions such as supporting ongoing operations in the Middle East.

Deterrence by Detection's strengths include affordability, near-term relevance, and feasibility. It is affordable because repurposing existing systems often costs little beyond what is already being spent, particularly for fungible assets such as ISR platforms. It is relevant because it involves systems that are already being fielded and thus can be implemented quickly. And it is feasible because it can be put into practice without the need to conclude new basing agreements or construct dedicated infrastructure.

### FIGURE 1: WESTERN PACIFIC UAS ORBITS IN DETERRENCE BY DETECTION




**Source**: CSBA analysis.[8]

7 In fiscal year (FY) 2023 dollars (total obligational authority), the cost estimate calculation is (24 MQ-9 x $9.70m) + (15 MQ-4C x $22.93m) + (7 RQ-4 x $22.93m) = $737.26m. Aircraft quantities come from Mahnken, Sharp, and Kim, *Deterrence by Detection*, p. 32. Aircraft costs come from Congressional Budget Office (CBO), *The U.S. Military's Force Structure: A Primer, 2021 Update* (May 2021), p. 98, https://www.cbo.gov/system/files/2021-05/57088-Force-Structure-Primer.pdf. Since CBO did not include a MQ-4C cost figure, the estimate assumes that it costs the same as the RQ-4. The estimate sums CBO's direct and indirect squadron costs, divides the sum by 12 to generate a per aircraft cost, and then converts the resulting figure to FY 2023 dollars using DoD, *National Defense Budget Estimates for FY 2023* (July 2022), Table 5-4, p. 59, https://comptroller.defense.gov/Portals/45/Documents/defbudget/FY2023/FY23_Green_Book.pdf. The main text presents the estimate as a range, not a point prediction, to capture the uncertainty inherent in this type of calculation. As Enthoven and Smith wrote, "It is better to be roughly right than precisely wrong." Alain C. Enthoven and K. Wayne Smith, *How Much Is Enough? Shaping the Defense Program 1961–1969* (New York: Harper & Row, 1971), p. 68.

8 Mahnken, Sharp, and Kim, *Deterrence by Detection*, p. 30.

## The Inseparability of Detection and Retaliation in Deterrence: A Response to Critics

The logic underpinning Deterrence by Detection is that surveillance with attribution strengthens deterrence. In Thomas Schelling's conception, deterrence involves "setting the stage" by threatening to retaliate against an adversary if he commits some unwanted action and "waiting" by maintaining the retaliatory threat indefinitely.[9] Waiting entails watching closely to detect whether the adversary takes the unwanted action, especially in tense situations characterized by the reciprocal fear of surprise attack.[10] Deterrence will fail if a transgressor believes he can act with impunity (because his misdeeds will go undetected and thus unpunished). As Jon Lindsay and Erik Gartzke note, "[D]etection provides the option for targeted retaliation."[11] Detection and retaliation thus represent inseparable aspects of deterrence. To deter successfully, one must persuade an adversary that its wrongdoing will be perceived and punished. Issuing a deterrent threat means promising both to spot the unwanted action and to penalize it.

Although Deterrence by Detection focuses on improving the detection aspect of deterrence, it recognizes that brandishing a credible retaliatory threat is also required to deter a determined adversary. Surveillance by itself is necessary but not sufficient. As Albert Wohlstetter argued, "Relying on [it] alone to prevent surprise would invite catastrophe and the loss of power to retaliate."[12] CSBA studies have acknowledged that Deterrence by Detection "is far from a panacea" and emphasized how improved surveillance supports "mass[ing] sufficient combat power to prevent a *fait accompli*" and "giving the U.S. alliance time to thwart the operation militarily."[13]

These explicit references to the importance of retaliation refute the ill-conceived critique that Deterrence by Detection "assumes detection is enough" and depends solely on "naming and shaming."[14] They also expose a misunderstanding in the critique that Deterrence by

9 Thomas C. Schelling, *Arms and Influence* (New Haven, CT: Yale University Press, 1966), pp. 71–72.

10 Ibid., p. 288; Thomas C. Schelling, *The Strategy of Conflict* (Cambridge, MA: Harvard University Press, 1960), p. 220; and Robert Jervis, *The Meaning of the Nuclear Revolution* (Ithaca, NY: Cornell University Press, 1989), p. 138.

11 Jon R. Lindsay and Erik Gartzke, "Coercion through Cyberspace: The Stability-Instability Paradox Revisited," in Kelly M. Greenhill and Peter Krause, eds., *Coercion: The Power to Hurt in International Politics* (New York: Oxford University Press, 2018), p. 192.

12 Albert Wohlstetter, "The Delicate Balance of Terror," *Foreign Affairs* 37, no. 2 (January 1959), p. 232.

13 Mahnken, Sharp, and Kim, *Deterrence by Detection*, pp. ii–iii; and Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, p. 4.

14 Emily Harding, "Bad Idea: Deterrence by Detection" (Washington, DC: Center for Strategic and International Studies [CSIS], December 2, 2021), https://defense360.csis.org/bad-idea-deterrence-by-detection/.

Detection failed in Ukraine, and thus may fail against China, because Russia invaded Ukraine despite extensive Allied intelligence disclosures.[15]

Deterrence failed in Ukraine because the threat of retaliation, such as it was, did not persuade Vladimir Putin to call off the attack. The allies performed superbly at surveillance, as evidenced by the remarkable degree of international agreement about Russia's behavior and culpability prior to the invasion.[16] As Kaupo Rosin, director general of the Estonian Foreign Intelligence Service, remarked, "Even though Russia was not deterred by the release of the intelligence information, what was achieved was that everybody was on the same sheet of music when the war started."[17] Effective surveillance expedited allied efforts to defend Ukraine and punish Russia, perhaps discouraging future aggressors from launching similar attacks. Alas, outstanding detection could not compensate for the weak retaliatory threat. This outcome in no way invalidates the usefulness of Deterrence by Detection. Rather, it reminds us that surveillance must always be backed by the credible threat of combat power to deter a committed aggressor.

## The Growing Influence of Deterrence by Detection

Deterrence by Detection has attracted interest from U.S. government officials, defense analysts, and military planners outside the United States. Numerous government officials have championed Deterrence by Detection concepts. The Commandant of the Marine Corps, General David Berger, advocated a Deterrence by Detection approach to dissuading China and Russia from committing acts of aggression.[18] In the weeks leading up to Russia's attack on Ukraine, he called for sharing ISR data to expose the Russian military buildup opposite Ukraine and build international opposition to Russian aggression.[19] Rear Admiral Mike Studeman, commander of the Office of Naval Intelligence, argued that Deterrence

15 Bryan Clark and Dan Patt, "The Pentagon Must 'Campaign' Against China, Not Hope for a Goal-Line Stand," *Defense One*, April 10, 2022, https://www.defenseone.com/ideas/2022/04/pentagon-must-campaign-against-china-not-hope-goal-line-stand/365453/.

16 Max Colchester and Warren P. Strobel, "U.S., Allies Fight Information War with Russia to Deter Ukraine Invasion," *Wall Street Journal*, February 9, 2022, https://www.wsj.com/articles/u-s-allies-fight-information-war-with-russia-to-deter-ukraine-invasion-11644402601.

17 Julian E. Barnes and Adam Entous, "How the U.S. Adopted a New Intelligence Playbook to Expose Russia's War Plans," *New York Times*, February 23, 2023, https://www.nytimes.com/2023/02/23/us/politics/intelligence-russia-us-ukraine-china.html.

18 David H. Berger, "Preparing for the Future: Marine Corps Support to Joint Operations in Contested Littorals," *Military Review* 101, no. 3 (May-June 2021), p. 9, https://www.armyupress.army.mil/Portals/7/military-review/Archives/English/MJ-21/Berger-print.pdf; Justin Katz, "U.S. Should Pursue 'Deterrence by Detection,' Says Marine Corps Commandant," *Breaking Defense*, September 1, 2021, https://breakingdefense.com/2021/09/us-should-pursue-deterrence-by-detection-says-marine-corps-commandant/; and U.S. Marine Corps, *A Concept for Stand-in Forces* (Washington, DC: Headquarters, U.S. Marine Corps, December 2021), p. 7, https://www.hqmc.marines.mil/Portals/142/Users/183/35/4535/211201_A%20Concept%20for%20Stand-In%20Forces.pdf.

19 Justin Katz, "Berger Calls for 'Deterrence by Detection' in Light of Russia-Ukraine Tensions," *Breaking Defense*, February 8, 2022, https://breakingdefense.com/2022/02/berger-calls-for-deterrence-by-detection-in-light-of-russia-ukraine-tensions/.

by Detection-style operations help counter Chinese and Russian propaganda by collecting incontrovertible proof of unprofessional behavior, such as the March 2023 incident caught on video in which Russian Su-27s dumped fuel on and collided with an American MQ-9, forcing it to crash into the Black Sea.[20] Bilal Saab and General Frank McKenzie, USMC (Ret.), former commander of U.S. Central Command, argued that Deterrence by Detection is the least expensive and most effective approach to preventing Iranian aggression.[21] They claimed that the United States and its allies have already used the approach to influence Iranian decision-making and behavior in the Middle East. Since its creation two years ago, Task Force 59 under U.S. Naval Forces Central Command has conducted Deterrence by Detection-style operations in the Middle East.[22]

Defense analysts have referenced Deterrence by Detection concepts while developing their own sophisticated assessments of NATO's force posture in Europe, the MQ-9's future, offensive advantage, crisis escalation, and distributed maritime operations.[23] Experts have also proposed applying Deterrence by Detection approaches beyond the Western Pacific and Eastern Europe. For example, Sameer Lalwani and his colleagues recommended that India and the United States cooperate on Deterrence by Detection-style initiatives.[24] The countries have seemingly made progress along these lines, as U.S. officials revealed that American

20 Colin Demarest, "China, Russia Propaganda Wither as Cameras Multiply, U.S. Admiral Says," *C4ISRNET*, April 5, 2023, https://www.c4isrnet.com/intel-geoint/2023/04/05/china-russia-propaganda-wither-as-cameras-multiply-us-admiral-says/.

21 Bilal Y. Saab and Frank McKenzie, "Deterring by Detection: A Cheap, Successful Way to Deter Iran," *Breaking Defense*, December 12, 2022, https://breakingdefense.com/2022/12/deterring-by-detection-a-cheap-successful-way-to-deter-iran/.

22 Jackson Barnett, "Task Force 59: The Future of the Navy's Unmanned Systems or a One-Off Win?" *FedScoop*, February 8, 2022, https://www.fedscoop.com/federal-judge-goes-against-justice-department-and-declines-to-stop-booz-allens-proposed-acquisition-of-everwatch/.

23 Alexander Lanoszka and Luis Simón, "A Military Drawdown in Germany? U.S. Force Posture in Europe from Trump to Biden," *The Washington Quarterly* 44, no. 1 (Spring 2021), p. 212; Sean Monaghan, "Five Steps NATO Should Take after the Nord Stream Pipeline Attack" (Washington, DC: CSIS, October 6, 2022), https://www.csis.org/analysis/five-steps-nato-should-take-after-nord-stream-pipeline-attack; Lawrence A. Stutzriem, *Reimagining the MQ-9 Reaper* (Arlington, VA: Mitchell Institute for Aerospace Studies, November 2021), pp. 15–16, http://mitchellaerospacepower.org/wp-content/uploads/2021/11/Reimagining_the_MQ-9_Reaper_Policy_Paper_30-1.pdf; Geoffrey T. Barnes, "Refocusing Reapers: Tangible Improvements Today That Prepare for the Future," *Air & Space Operations Review* 1, no. 4 (Winter 2022), p. 26, https://www.airuniversity.af.edu/Portals/10/ASOR/Journals/Volume-1_Number-4/Barnes.pdf; Antonio Calcara et al., "Will the Drone Always Get Through? Offensive Myths and Defensive Realities," *Security Studies* 31, no. 5 (December 2022), pp. 809, 819–820; Erik Lin-Greenberg, "Wargame of Drones: Remotely Piloted Aircraft and Crisis Escalation," *Journal of Conflict Resolution* 66, no. 10 (November 2022), p. 1741; and Samuel Winegar, "The Eyes of the Fleet: Corbett and Distributed Maritime Operations in the First Island Chain," *Yale Journal of International Affairs*, December 5, 2022, https://www.yalejournal.org/publications/the-eyes-of-the-fleet-corbett-and-distributed-maritime-operations-in-the-first-island-chain.

24 Sameer Lalwani et al., *Toward a Mature Defense Partnership: Insights from a U.S.-India Strategic Dialogue* (Washington, DC: Henry L. Stimson Center, November 2021), pp. 19–23, https://www.stimson.org/wp-content/uploads/2021/11/US-India-Report.pdf.

intelligence sharing helped India repel the Chinese military's border incursion into the Arunachal Pradesh region in 2022.[25]

Interest in Deterrence by Detection has not been confined to the United States. The Japan Maritime Self-Defense Force Command and Staff College published a translated summary of the concept.[26] Peter Layton outlined how Australia could implement it to counter malicious Chinese activity.[27] Siddharth Sridhar suggested that India use Deterrence by Detection to address its simmering border disputes with China.[28]Jørn Qviller and his colleagues described how Norway and the United States could implement it together.[29] Finally, defense analysts in China have taken note. Writing in the journal *Modern Defense Technology*, four Chinese researchers examined applying the concept to China's circumstances.[30]

## Conclusion

Deterrence by Detection-style ideas have gained momentum since CSBA first proposed the concept in 2020. One of the most significant recent developments came in May 2022 when the Quad established the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA), an initiative closely mirroring Deterrence by Detection. The next chapter uses Deterrence by Detection as a reference point to analyze IPMDA's objectives and activities.

25 Paul D. Shinkman, "U.S. Intel Helped India Rout China in 2022 Border Clash: Sources," *U.S. News & World Report*, March 20, 2023, https://www.usnews.com/news/world-report/articles/2023-03-20/u-s-intel-helped-india-rout-china-in-2022-border-clash-sources.

26 Japan Maritime Self-Defense Force (JMSDF), "'Deterrence by Detection' Concept: The Role of Unmanned Aerial Vehicle Systems in Great Power Competition" (Tokyo: JMSDF Command and Staff College, June 30, 2020), https://www.mod.go.jp/msdf/navcol/index.html?c=topics&id=083.

27 Peter Layton, *China's Enduring Grey-Zone Challenge* (Canberra: Air and Space Power Centre, 2021), pp. 81–84, https://airpower.airforce.gov.au/sites/default/files/2021-07/Chinas%20Enduring%20Greyzone%20Challenge_0.pdf.

28 Siddharth Sridhar, "India's Key to Keeping the Status Quo on Its Border With China," *The Diplomat*, March 2, 2023, https://thediplomat.com/2023/03/indias-key-to-keeping-the-status-quo-on-its-border-with-china/.

29 Jørn Qviller et al., "Stand-in Forces and Integrated Deterrence: The Marine Corps and the Norwegian Armed Forces," *Marine Corps Gazette* 106, no. 5 (May 2022), p. 44.

30 Zhan-fu Song et al., "Research on UAV Supporting Ground Air Defense Operations," *Modern Defense Technology* 50, no. 5 (October 2022), pp. 22–27.

CHAPTER 2

# A Critical Appraisal of the Indo-Pacific Partnership for Maritime Domain Awareness

Over the past year, concerns continued growing about a future conflict in the Indo-Pacific region. The gravest worries revolved around a potential Chinese military operation against Taiwan occurring sooner rather than later.[31] Taiwan-related apprehension increased with former U.S. House Speaker Nancy Pelosi's summer 2022 visit to Taiwan and Chinese President Xi Jinping's despotic seizure of a third term in power.

Meanwhile, other regional security trends also deteriorated, notably in the maritime domain. Smuggling, trafficking, and violent extremist activities represented areas of continuing concern. Industrial and semi-industrial fishing vessels flagged to Asia conducted over half of globally reported illegal, unreported, and unregulated fishing.[32] Many of these vessels came from China, which sponsors the world's largest distant-water fishing fleet.[33] From 1993 to 2010, one in 10 militarized interstate disputes worldwide involved fisheries, fishers, or fishing vessels.[34] Mutual recriminations over illegal fishing, a hugely profitable activity, could push Indo-Pacific nations to the brink of war.

31 Edward Wong, David E. Sanger, and Amy Qin, "U.S. Officials Grow More Concerned About Potential Action by China on Taiwan," *New York Times*, July 25, 2022, https://www.nytimes.com/2022/07/25/us/politics/china-taiwan-biden-pelosi.html.

32 Dan Collyns, "Illegal Fishing Spurs Billions in Losses for Developing Countries, Study Says," *Guardian*, October 26, 2022, https://www.theguardian.com/environment/2022/oct/26/illegal-fishing-billions-losses-developing-countries.

33 Estimates of the size of China's distant-water fishing fleet vary from under 2,000 to nearly 17,000 vessels. Miren Gutiérrez et al., *China's Distant-Water Fishing Fleet: Scale, Impact, and Governance* (London, ODI, June 2020), p. 15, https://cdn.odi.org/media/documents/chinesedistantwaterfishing_web.pdf.

34 Cullen Hendrix and Paige Roberts, "One in 10 Interstate Disputes Are Fishy – and the Implications Stink," *New Security Beat*, Woodrow Wilson International Center for Scholars, December 20, 2017, https://www.newsecuritybeat.org/2017/12/10-interstate-disputes-fishy-implications-stink/.

Recognizing these challenges, the leaders of the United States, Australia, Japan, and India announced in May 2022 the creation of the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA), an initiative resembling CSBA's Deterrence by Detection operational concept. IPMDA aims to improve the common operating picture of participating nations by disseminating unclassified data collected by commercial satellites. The creation of IPMDA provides an opportunity to advance Deterrence by Detection's ideas.

This chapter uses Deterrence by Detection as a touchstone to evaluate IPMDA's objectives and activities. The chapter advances two arguments. First, although IPMDA focuses on law enforcement and maritime safety, Quad leaders could repurpose it to military competition with China if they judged doing so to be in their interests. Second, relative to the classified government systems emphasized by Deterrence by Detection, IPMDA's reliance on commercial space-based collection implies that it will perform well at sharing data broadly but likely fail to provide information that is sufficiently granular to satisfy participating nations' information needs.

Regardless of whether IPMDA ever transitions to military operations at the behest of Quad leaders, it would benefit from incorporating additional ISR sources beyond commercial space-based collection. Integrating unmanned aircraft systems (UAS) into IPMDA would meet this need at a modest cost, as argued in Chapters 3 and 4.

## IPMDA Objectives: Focused on Law Enforcement and Maritime Safety, Adaptable to Military Competition

Deterrence by Detection recommends using primarily *military-directed* ISR capabilities to monitor and discourage Chinese military aggression in the South China Sea, East China Sea, and Taiwan Strait.[35] In contrast, IPMDA proposes using primarily *commercially directed* ISR capabilities to monitor illegal fishing, humanitarian crises, maritime security, marine conservation, and related issues in the Pacific Islands, Southeast Asia, and the Indian Ocean.[36] In short, Deterrence by Detection focuses on military competition with China near geographic flashpoints, whereas IPMDA focuses on law enforcement and maritime safety across the region.

IPMDA's objectives exclude anything related to military-directed ISR monitoring of Chinese warships. The Quad countries possess different threat perceptions and national policies

35 "Military directed" includes ISR systems owned or operated by contractors who conduct activities primarily at the behest of military sponsors.

36 White House, "Background Press Call Previewing President Biden's Final Day in Japan"; White House, "Fact Sheet: Quad Leaders' Tokyo Summit 2022"; and White House, "Readout of President Joe Biden's Participation in the East Asia Summit," November 13, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/11/13/readout-of-president-joe-bidens-participation-in-the-east-asia-summit/.

on China.[37] IPMDA only includes objectives enjoying strong Quad and regional support, such as combating illegal fishing and tracking vessels that turn off or spoof their automatic identification systems (AIS) to conceal their identities. Of course, China commits these transgressions frequently. It ranks worst in the world for illegal fishing according to international oversight groups.[38] In 2021, it enacted a law encouraging Chinese vessels in Chinese-claimed waters to turn off AIS, a move Beijing said was necessary to thwart collection by foreign intelligence agencies.[39]

Despite IPMDA's emphasis on law enforcement and maritime safety, some in China believe that it will inevitably monitor the Chinese navy. As Hu Bo, director of the South China Sea Strategic Situation Probing Initiative, argued, "The move toward Chinese fishing vessels is likely to be just an 'appetizer[.]' Chinese government and Coast Guard vessels, as well as warships, will also become next targets under the surveillance."[40] For its part, the Chinese foreign ministry denounced IPMDA for "building small cliques and stoking bloc confrontation."[41]

The Quad and China both have reasons to characterize IPMDA's objectives in particular ways. For defense strategists, however, the question remains how IPMDA will affect the regional balance of power.

IPMDA develops organizational infrastructure and surveillance practices that the Quad and its partners could repurpose for military operations, including monitoring a Chinese move against Taiwan, if political leaders judged doing so to be collectively advantageous. The Quad has pooled political power in IPMDA that it can convert into military power later if desired.[42] A commercial satellite imaging merchant shipping traffic could just as easily image a naval exercise. As retired Indian Army Major General Dhruv Katoch noted after IPMDA's creation, "While the Quad as of now is not a security organization, it has the potential to

37 William Choong, "The Quad and the Indo-Pacific: Going Slow to Go Further," *Fulcrum*, October 4, 2021, https://fulcrum.sg/the-quad-and-the-indo-pacific-going-slow-to-go-further/; and Ralph Jennings, "China Expected to Mount Strong Defense Against US-Backed Maritime Surveillance," *VOA*, June 4, 2022, https://www.voanews.com/a/china-expected-to-mount-strong-defense-against-us-backed-maritime-surveillance-/6603107.html.

38 IUU Fishing Index, "Rankings," accessed November 21, 2022, https://iuufishingindex.net/ranking.

39 Brett Tingley, "Scores of 'Dark Vessels' Belonging to China's Maritime Militias Are Operating in Contested Waters," *The Drive*, February 22, 2022, https://www.thedrive.com/the-war-zone/44390/scores-of-dark-vessels-belonging-to-chinas-maritime-militias-are-operating-in-contested-waters.

40 Hu Bo, "Chinese Fishing Boats Ridiculously Become a Substantive Security Target of Quad," *Global Times*, May 25, 2022, https://www.globaltimes.cn/page/202205/1266543.shtml.

41 Zaheena Rasheed, "Quad Launches 'Anti-China' Maritime Surveillance Plan," *Al Jazeera,* May 28, 2022, https://www.aljazeera.com/news/2022/5/28/why-has-the-quad-launched-an-anti-china-surveillance-plan.

42 Shruti Pandalai and Abhay Kumar Singh, "Quad's Maritime Domain Awareness Initiative Needs Time to Deliver," *IDSA Comment*, June 24, 2022, https://idsa.in/idsacomments/Quads-Maritime-Domain-240622.

quickly metamorphose into one."[43] The United States and its allies used a similar method throughout the Cold War, often to good effect, by creating political institutions that served as tappable reservoirs of latent military strength.[44] If the Quad eventually decided to use IPMDA in a more military-focused role, the resulting military-civilian hybrid model would mirror the approach favored by China, which does not distinguish between military competition and law enforcement in the same way that the United States and its allies do.[45]

If pressed, Quad leaders should forthrightly acknowledge IPMDA's military potential, and thereby implicitly threaten its actualization, to avoid the self-defeating contradiction of denying the existence of latent military strength where it so obviously exists. Denying IPMDA's military applicability seems especially pointless given that it could help participating Indo-Pacific nations tip and cue their classified intelligence capabilities, as noted in the next section. The United States and its allies spent much of the 2000s and 2010s soft-pedaling their responses to China's rise out of concern that acknowledging strategic competition would worsen it.[46] Allied evasiveness did not stanch intensifying rivalries with China then, and it will not prevent tensions over IPMDA now. Quad leaders should instead speak softly, meaning candidly, about how IPMDA can potentially make their big stick bigger.[47]

## IPMDA Activities: Commercial Space-Based Collection Necessary but Insufficient

Even if Quad leaders never repurpose IPMDA for military operations, they could improve it by incorporating additional ISR sources to supplement the commercial space-based collection already included. Identifying the optimal ISR sources to add requires first understanding the strengths and limitations of commercial collection to determine where gaps exist.

According to public statements, IPMDA's most significant activity involves sharing unclassified data collected by commercial satellites to bolster information sharing across regional fusion centers, including in India, Singapore, the Solomon Islands, and Vanuatu.[48] Deterrence by Detection also proposes harnessing commercially available unclassified data

43 Ravi Buddhavarapu, "The Quad's New Maritime Initiative Has Potential to Spur Militarization of the Indo-Pacific," *CNBC*, June 8, 2022, https://www.cnbc.com/2022/06/09/quads-maritime-initiative-could-spur-militarization-of-indo-pacific.html.

44 Thomas G. Mahnken, *Forging the Tools of 21st Century Great Power Competition* (Washington, DC: CSBA, March 2020), https://csbaonline.org/research/publications/forging-the-tools-of-21st-century-great-power-competition.

45 Alessio Patalano, "When Strategy Is 'Hybrid' and Not 'Grey': Reviewing Chinese Military and Constabulary Coercion at Sea," *The Pacific Review* 31, no. 6 (2018), pp. 811–839.

46 Aaron L. Friedberg, *Getting China Wrong* (New York: Polity, 2022).

47 As a suffragist, Teddy Roosevelt might have wanted this sentence to cite Carol Cohn, "Sex and Death in the Rational World of Defense Intellectuals," *Signs* 12, no. 4 (Summer 1987), pp. 687–718.

48 White House, "Background Press Call Previewing President Biden's Final Day in Japan"; and White House, "Fact Sheet: Quad Leaders' Tokyo Summit 2022."

to improve maritime domain awareness, although it envisions using commercial collection to complement, not replace, classified government collection. Some Quad leaders have championed IPMDA strictly in terms of commercial collection, as if it consists only of disseminating commercial geospatial intelligence.[49] Expert commentary has mostly praised this approach in general terms and echoed governmental messaging.[50] For example, one analyst hailed IPMDA as a "game changer" for harnessing breakthroughs in commercial space-based remote sensing (**Text Box 1**).[51]

The Quad pledged to support IPMDA through funding, training, consultations, and technology. It vowed to spend at least $50 billion on Asia-Pacific infrastructure projects through 2027, although public statements have not clarified whether IPMDA will receive part of those funds or separate funds.[52] The Quad also committed to provide IPMDA-related training, consult with regional partners about IPMDA opportunities, and identify promising future technologies as IPMDA proceeds.[53]

The United States made slow but steady progress on these promises throughout 2022. The National Reconnaissance Office signed three new multiyear contracts for commercial space-based imagery.[54] In June, the White House issued National Security Memorandum-11 directing government-wide actions to combat illegal, unreported, and unregulated fishing.[55] Senior U.S. officials reaffirmed American support for IPMDA at ministerial meetings with India and discussed the initiative during meetings with New Zealand and Indonesia.[56] In November, Vice President Kamala Harris revealed that the Philippines is already receiving

49 White House, "Remarks by Vice President Harris Aboard the Philippine Coast Guard Ship Teresa Magbanua."

50 A handful of observers have offered more specific constructive critiques. In particular, see Zack Cooper and Gregory Poling, "The Quad Goes to Sea," *War on the Rocks*, May 24, 2022, https://warontherocks.com/2022/05/the-quad-goes-to-sea/; and Jasmin Alsaied, "How to Make the Indo-Pacific Partnership for Maritime Domain Awareness Work," *The Diplomat*, October 11, 2022, https://thediplomat.com/2022/10/how-to-make-the-indo-pacific-partnership-for-maritime-domain-awareness-work/.

51 David Brewster, "New Satellite-Based Technologies a Game Changer for Indo-Pacific Maritime Security," *The Strategist*, Australian Strategic Policy Institute, July 13, 2022, https://www.aspistrategist.org.au/new-satellite-based-technologies-a-game-changer-for-indo-pacific-maritime-security/.

52 AFP, "Quad Plans $50 Bn Infrastructure Investment in Asia-Pacific: Kishida," May 24, 2022, https://www.barrons.com/news/quad-plans-50-bn-infrastructure-investment-in-asia-pacific-kishida-01653373508.

53 White House, "Fact Sheet: Quad Leaders' Tokyo Summit 2022"; and White House, "Quad Joint Leaders' Statement."

54 Government Accountability Office, *Actions Needed to Better Use Commercial Satellite Imagery and Analytics*, September 2022, p. 10, https://www.gao.gov/assets/gao-22-106106.pdf.

55 White House, "Memorandum on Combating Illegal, Unreported, and Unregulated Fishing and Associated Labor Abuses," June 27, 2022, https://www.whitehouse.gov/briefing-room/presidential-actions/2022/06/27/memorandum-on-combating-illegal-unreported-and-unregulated-fishing-and-associated-labor-abuses/.

56 India Ministry of External Affairs, "India-U.S.A. 2+2 Inter-sessional Dialogue and India-U.S.A. Maritime Security Dialogue," September 7–8, 2022; White House, "Background Press Call by a Senior Administration Official on President Biden's Meeting with Prime Minister Jacinda Ardern of New Zealand," May 31, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/05/31/background-press-call-by-a-senior-administration-official-on-president-bidens-meeting-with-prime-minister-jacinda-ardern-of-new-zealand/; and DoD, "Readout of Secretary of Defense Lloyd J. Austin III Meeting With Indonesia Minister of Defense Prabowo Subianto," June 10, 2022, https://www.defense.gov/News/Releases/Release/Article/3059830/readout-of-secretary-of-defense-lloyd-j-austin-iii-meeting-with-indonesia-minis/.

IPMDA data, along with "other partners here in Southeast Asia," and noted that more satellites supporting IPMDA would launch in December.[57]

### Recent Breakthroughs in Space-Based Commercial Systems

Today, a growing number of commercial space-based remote sensing companies are expanding access to an emerging market for collection and analysis of intelligence from proliferated constellations of small satellites.[58] This paradigm of commercial space-based systems can provide one alternative to the current constraints of classified U.S. space systems. Commercial space products and services leverage advances in low-cost launch, power and cooling systems, on-board processor and computing miniaturization, and artificial intelligence and machine learning (AI/ML) to make these capabilities more affordable and accessible for nontraditional (i.e., non-governmental) users as well as governments.[59] Commercial space companies are replicating and, in certain respects, rapidly advancing technologies and techniques traditionally restricted to a small number of technologically advanced national governments.

For example, Planet is building a "megaconstellation" of cheap small satellites for overhead imaging. Each of Planet's "Dove" satellites is about the size of a shoebox. Although a Dove satellite lacks the spatial resolution of classified U.S. systems, it can take 10,000 pictures a day over an area equivalent to the size of Mexico. Planet's entire constellation of hundreds of Dove satellites will be able to photograph the entire planet at least once every 24 hours.[60] Planet is also working to field a few high-resolution satellites capable of following up on tipping from Dove collection with additional fidelity and resolution.

Companies such as Capella and ICEYE are building constellations of commercial synthetic aperture radar (SAR) satellites. Critically, these systems can collect at night and through cloud cover. Again, these satellites do not meet the highly classified resolution standards of historical and current U.S. satellites, but their value lies in rapid revisit rates over large coverage areas. Capella, which provides data to the U.S. Air Force, can provide SAR collection within 20 minutes of being tasked.[61] Given the speeds at which maritime targets travel, achieving a temporal resolution of 20 minutes from space is operationally relevant when tasking other ISR, law enforcement, or military assets to respond.

57 White House, "Remarks by Vice President Harris Aboard the Philippine Coast Guard Ship Teresa Magbanua," November 22, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/11/22/remarks-by-vice-president-harris-aboard-the-philippine-coast-guard-ship-teresa-magbanua/.

58 This textbox originally appeared in the appendix of Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, pp. 48–50.

59 Early government investment in these technologies, particularly by DoD, helped bring them to commercial markets.

60 Contrary to what some observers expect, coverage of maritime areas remains relatively sparse due to limited business-case applications of interest.

61 Capella Space, "Our Story," accessed April 23, 2021, available at https://www.capellaspace.com/about-us/our-story/.

HawkEye360 is a relatively unique entrant in the commercial space-based remote sensing field. Its satellites perform geolocation of radiofrequency (RF) emissions. Although this type of capability has historically been the exclusive realm of well-resourced governments, developers such as HawkEye360 have demonstrated the capability to track AIS transponder emissions from ships. An AIS transponder broadcasts a vessel's identity, position, course, and speed. These systems can also share information related to destination and cargo type. An AIS transponder shares its information with AIS transponders aboard other ships and land-based AIS receivers, aiding collision avoidance, search and rescue, and maritime law enforcement and security. Although AIS was originally intended for terrestrial use over distances of roughly 50 miles, in 2005, a satellite successfully detected AIS broadcasts from space.[62] Today, commercial space-based RF can collect transmissions to derive insights about global commerce and security, as well as identify platforms that may not have AIS active (so-called "dark targets") and potentially merit interrogation using other assets.

Commercial space companies are also increasing their sophistication, including using distributed sensing algorithms to fuse information across large constellations, formation flying, and rapid production of heterogeneously customized satellites at current scales of one to two dozen per month.[63]

## Commercial Collection Advantages and Disadvantages

If IPMDA primarily consists of disseminating commercial space-based collection, then its strengths and limitations will reflect those of commercial collection. Reviewing those attributes allows us to formulate concrete expectations about IPMDA's future performance (**Table 1**).

62 "Satellite AIS – Addressing Some Misconceptions," *Big Ocean Data*, April 22, 2016, available at https://www.bigoceandata.com/white-paper/satellite-ais-addressing-some-misconceptions/.

63 "HawkEye 360 to Be First Commercial Company to Use Formation-Flying Satellites," *CBS Boston*, accessed April 23, 2021, available at https://boston.cbslocal.com/video/5226773-hawkeye-360-to-be-first-commercial-company-to-use-formation-flying-satellites/.

### TABLE 1: COMMERCIAL SPACE-BASED COLLECTION ADVANTAGES AND DISADVANTAGES

| Advantages | Disadvantages |
|---|---|
| High shareability | Less robust information security |
| Growing ubiquity | Responsiveness limited by other commitments |
| Complementarity with classified systems | Constrained resolution and access |

**Source**: CSBA analysis.

Advantages: Commercial space-based collection has delivered capability that previously existed only with highly classified, government-operated space programs. From a governmental perspective, commercial collection's greatest strengths are high shareability, growing ubiquity, and complementarity with classified systems.[64]

- **High shareability**. Commercial space-based collection generates shareable unclassified data that analysts can distribute freely across international and organizational boundaries, so long as the vendor and applicable regulatory regimes permit doing so. This shareability tremendously improves dissemination, the critical but oft-overlooked final step in the intelligence cycle.[65] As David Gauthier, director of the National Geospatial-Intelligence Agency's Commercial and Business Operations Group, remarked, "Commercial [collection] makes it easy to share these insights with our allies and partners."[66] Having access to commercial collection helps working-level intelligence analysts avoid soul-crushing dissemination processes that discourage creating baseline products to share with allies and partners (**Text Box 2**).[67]
- **Growing ubiquity**. Commercial space-based collection firms continue to attain broader geographic coverage, faster revisit rates, diversified spectral content, and improved analytic enrichments, offering customers a rich stream of decision-quality

64 National System for Geospatial Intelligence, *Geospatial Intelligence (GEOINT) Basic Doctrine, Publication 1.0*, April 2018, p. 8, https://www.nga.mil/resources/GEOINT_Basic_Doctrine_Publication_10_.html.

65 The U.S. intelligence community previously included feedback as a sixth and final step after dissemination. Office of the Director of National Intelligence, *U.S. National Intelligence – An Overview 2013*, April 10, 2013, p. 4, https://www.dni.gov/files/documents/USNI%202013%20Overview_web.pdf.

66 National Geospatial-Intelligence Agency (NGA), "NGA Looks to Commercial RF Emitter Data for Non-Traditional Approach," September 27, 2021, https://www.nga.mil/news/NGA_looks_to_commercial_RF_emitter_data_for_non-tr.html.

67 A baseline product summarizes an intelligence target, location, or personality – frequently using less sensitive sources and methods – to create a shared reference point from which analysts can subsequently "determine the progress of specific events or situations." DoD , *Geospatial Intelligence in Joint Operations, Joint Publication 2-03*, July 6, 2017, pp. G-8–G-9, https://irp.fas.org/doddir/dod/jp2_03.pdf.

data.[68] Commercial satellites typically conduct repetitive wide-area collection rather than intermittent spot collection based on discrete tasking.[69] As a result, commercial collection generates massive amounts of data that are incredibly useful for anomaly and change detection, image time series analysis, pattern of life assessment, and other forms of activity-based intelligence (ABI).[70] Governments can pay for only their desired portion of the commercial data through purchasing services, avoiding the "all or nothing" dilemma of classified government systems.[71]

- **Complementarity with classified systems**. Commercial space-based collection complements classified government systems, including those emphasized in Deterrence by Detection, by tipping and cueing them to collection opportunities, corroborating their findings, and freeing them up to focus on the most sensitive targets.[72] Applying ABI analysis to commercial collection can generate high-quality "finds" of prospective intelligence targets, setting up scarce classified assets to execute the demanding "fixes" and "tracks" of those targets using high-resolution sensors.[73] Executing this commercial-to-classified alley-oop is more economical, all else being equal, than dispatching scarce classified systems to interrogate prospective targets, a resource-intensive way to hunt for needles in haystacks.

Commercial collection's advantages will shape IPMDA's performance. First, high shareability implies that IPMDA will increase information flows both across nations and within governments. Increased sharing should not prove particularly difficult, costly, or time-consuming, contrary to public claims by observers who may have mistakenly assumed IPMDA-passed commercial collection would mimic traditional classified intelligence sharing.[74] Doubling the number of intelligence products shared annually within three years (by

68 NGA, *Commercial GEOINT Strategy, 2018 Update*, August 2, 2018, p. 2, https://www.nga.mil/assets/files/COMMERCIAL_GEOINT_STRATEGY_PR18-426.pdf.

69 Sandra I. Erwin, "Space Sector: Remote Sensing Firms Frustrated by Red Tape," *National Defense* 101, no. 758 (January 2017), p. 32.

70 Thomas M. Lillesand, Ralph W. Kiefer, and Jonathan W. Chipman, *Remote Sensing and Image Interpretation*, 7th edition (Hoboken, NJ: Wiley, 2015), pp. 582–591; and Nicholas Lapinski, "AI, Commercial Firms Key to Future of GEOINT," *National Defense*, August 20, 2021, https://www.nationaldefensemagazine.org/articles/2021/8/20/ai-commercial-firms-key-to-future-of-geoint.

71 The dilemma is, pay for the entire expensive satellite and get everything or do not pay for it and get nothing.

72 Tipping and cueing means using one intelligence discipline, asset, or sensor to cross-cue or initiate collection by another more precise sensor. DoD, *Joint and National Intelligence Support to Military Operations, Joint Publication 2-01*, July 5, 2017, p. III-29, https://irp.fas.org/doddir/dod/jp2_01.pdf.

73 NGA, "NGA Looks to Commercial RF Emitter Data for Non-Traditional Approach." The find-fix-track terminology refers to the "F2T2EA" dynamic kill chain model. U.S. Air Force, *Targeting, Air Force Doctrine Publication 3-60*, November 12, 2021, pp. 27–30, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-60/3-60-AFDP-TARGETING.pdf.

74 Colin Clark, "Quad's Indo-Pacific Ship Tracking 'Fusion' Will Be Expensive and Hard," *Breaking Defense*, May 25, 2022, https://breakingdefense.com/2022/05/quads-indo-pacific-ship-tracking-fusion-will-be-expensive-and-hard/.

2026) represents a reasonable goal for IPMDA based on the U.S. government's experience with domestic information sharing on counterterrorism.[75]

Second, growing ubiquity suggests that IPMDA will deliver relevant information across the wide range of maritime activities and geographic locations of concern to participating nations. No matter how small or remote, each nation should obtain at least some valuable information about its top concerns by participating in IPMDA.

Third, complementarity with classified systems means that IPMDA will provide participating nations with the opportunity to tip and cue their classified intelligence capabilities to refine collection. Each nation must decide whether to use IPMDA-passed information in that way. Yet, the opportunity will surely exist.

### How Flawed Dissemination Processes Hinder Working-Level Intelligence Sharing

Current U.S. intelligence dissemination processes hinder sharing information with allies and partners. Two problems faced by working-level analysts, misclassified data and slow approvals, illustrate the challenge.

Misclassified data streams in research tools: Widely used intelligence fusion research tools sometimes portray individual unenriched data streams – such as unclassified AIS collection – as more highly classified than they really are.[76] This overclassification causes headaches for the frontline analyst who invests enormous time and effort into performing highly classified research but cannot easily convert that research into a sanitized product shareable with allies and partners.[77] In effect, the analyst must build every product twice: once in a more classified form to support U.S. decision-making, and again in a less classified form to support allies and partners. Pressed for time and juggling multiple tasks, many analysts are forced to prioritize producing for their chain of command and thus skimp on producing for allies.

Slow approvals for foreign disclosures: Frontline analysts supporting military operations typically submit proposed intelligence shares to beleaguered foreign disclosure officers (FDOs) located in regional headquarters or the United States. FDOs often lack the personnel to support around-the-clock operations. As a result, time zone differences – not to mention analytical and administrative delays, including those stemming

75 Offices of Inspector General of the Intelligence Community, Department of Homeland Security, and Department of Justice, *Review of Domestic Sharing of Counterterrorism Information*, March 2017, p. 8, https://www.dni.gov/files/documents/Newsroom/Domestic_Sharing_Counterterrorism_Information_Report.pdf.

76 For a general discussion of these tools, see Michael Tiefel and Andrew Orchard, "Battlespace Awareness Tools Are Central to Fleet Readiness," *CIMSEC*, December 6, 2021, https://cimsec.org/battlespace-awareness-tools-are-central-to-fleet-readiness/.

77 The tools often possess the functionality to adjust analysis to different classification levels. This functionality toggles on or off individual data streams based on classification. However, it does not correct misclassified streams.

from error-prone email and SharePoint workflows – result in many intelligence shares not reaching allies and partners until 24 hours or more after collection occurred. At that point, the intelligence is often worthless operationally. Sharing it risks insulting allies and partners by implying that they cannot differentiate good intelligence from bad intelligence. Since intelligence sharing tends to proceed transactionally, following a tit-for-tat pattern of reciprocation, delivering stale intelligence to allies and partners virtually guarantees getting the same in return.

Disseminating commercial space-based collection through IPMDA should alleviate these problems. If commercial collection flows automatically to participating nations and they know how to use it, then the U.S. government can avoid acting as the bumbling middleman. Freed from the burdens of churning out two versions of every product and pestering FDOs for approvals, U.S. intelligence analysts can devote more time to casing hard targets, cultivating new sources and methods, and performing other demanding tasks that are key to out-competing U.S. adversaries in the information domain.

Disadvantages: Despite its strengths, commercial space-based collection generally cannot match the information security, responsiveness, and resolution and access provided by classified government systems, the focal point of Deterrence by Detection.[78] These three factors limit commercial collection from a governmental perspective.

- **Less robust information security**. Commercial remote sensing firms lack the resources and authorities used by the U.S. government to secure information, meaning firms generally cannot match the protections built into U.S. classified government systems. Less secure information flows during satellite tasking and acquisition might leave commercial collection vulnerable to outside disruption by malicious actors. If disruption were to occur, any government dependent on that collection might find itself missing a critical data stream. Nevertheless, the large quantities of satellites operated by commercial providers can give their constellations greater resiliency than constellations composed of fewer satellites.[79] Additionally, certain commercial remote sensing firms might have stronger information security than certain governments outside the United States.
- **Responsiveness limited by other commitments**. Commercial remote sensing firms often work with diverse customers from the private, public, and non-profit sectors, meaning they cannot respond to government needs as unrelentingly as dedicated government or contracting organizations. Firms facing competing demands from customers must make tradeoffs based on business considerations such as profit, growth,

78 National System for Geospatial Intelligence, *Geospatial Intelligence (GEOINT) Basic Doctrine,* p. 8.

79 Jamie Morin and Robert S. Wilson, *Leveraging Commercial Space for National Security* (Arlington, VA: Center for Space Policy and Strategy, Aerospace Corporation, November 2020), p. 7, https://csps.aerospace.org/sites/default/files/2021-08/Morin-Wilson_Leveraging_20201113.pdf.

and competition. In this calculus, government customers do not automatically trump other customers simply because they are governments. Firms use the same considerations to determine their internal plans and external offerings. Government desires will not dictate their business decisions, although government contracts can influence those decisions.

- **Constrained resolution and access**. Commercial space-based collection generally cannot match the high resolution and exquisite access provided by classified government systems.[80] Take satellite imagery as an example. U.S. photoreconnaissance satellites achieved spatial resolutions of less than 60cm in the 1980s.[81] Today, they operate even closer to the maximum resolution possible given the physical limitations imposed by diffraction on imaging system resolution.[82] In contrast, commercial panchromatic imagery's highest resolutions currently range from 25cm to 120cm – sharp images, to be sure, but very roughly on par with government collection 40 years ago.[83] Commercial firms may not image as sharply or widely as technology would permit because of government regulations protecting national security and business-case uncertainties, although these constraints vary by country.[84]

Commercial collection's disadvantages will shape IPMDA's performance. First, less robust information security implies that IPMDA will face the continuous risk of disruption by China or another actor opposed to its activities. If China planned a maritime incursion and knew that defenders or third-party monitors relied on IPMDA-passed information, then it might disrupt the commercial collection, whether kinetically or non-kinetically, to eliminate opposition to its move or attribution after the fact.

Second, limitations on responsiveness mean that IPMDA will remain vulnerable to pressures placed on the commercial firms supporting it. The Chinese government could create such pressures directly or indirectly using predatory investments, regulatory actions, bribes, or other forms of intimidation.

80 Steven C. Boraz, "Maritime Domain Awareness," *Naval War College Review* 62, no. 3 (Summer 2009), pp. 142–143, https://digital-commons.usnwc.edu/cgi/viewcontent.cgi?article=1694&context=nwc-review.

81 Robert A. McDonald, M. Sam Araki, and Patrick Widlake, "The 4C1000 Seven Tenets for the 21st Century – The Innovation Secret at the National Reconnaissance Office and Silicon Valley," *National Reconnaissance Journal of the Discipline and Practice* (June 2020), pp. 6–7, https://www.nro.gov/Portals/65/documents/history/csnr/articles/NRO_Journal_4C1000_Seven_Tenets_for_The_21st_Century_Pre-Print_7-2020.pdf?ver=2020-07-09-114911-710.

82 Greg Gbur, "How Well Can the Government Spy on Us via Satellite?" *Skulls in the Stars*, June 13, 2012, https://skullsinthestars.com/2012/06/13/how-well-can-the-government-spy-on-us-via-satellite/.

83 National Oceanic and Atmospheric Administration (NOAA), Commercial Remote Sensing Regulatory Affairs, "Remote Sensing License Tiering," Q3 2022, p. 3, https://www.nesdis.noaa.gov/s3/2022-11/Q3-2022_ForeignBenchmarks_Final.pdf.

84 Jeff Foust, "U.S. Government to Allow Sale of High-Resolution Commercial Satellite Images of Israel," *Space News*, July 18, 2020, https://spacenews.com/u-s-government-to-allow-sale-of-high-resolution-commercial-satellite-images-of-israel/; and Theresa Hitchens, "Exclusive: Amid National Security Concerns, U.S. Slaps Overhead Time Limits on Satellites," *Breaking Defense*, November 5, 2021, https://breakingdefense.com/2021/11/exclusive-amid-national-security-concerns-us-slaps-time-limits-on-overhead-satellites/.

Third, constrained resolution and access suggest that IPMDA will struggle to support law enforcement and other operations requiring finer-grained intelligence. To use an example offered previously by Quad leaders, consider a potential coast guard interdiction of a vessel suspected of illicit activity.[85] Imagine that analysts have an intelligence gap regarding whether the vessel is affiliated with a militia, as are hundreds of Chinese ships.[86] Using IPMDA-passed information to dispatch coast guardsmen to interdict the vessel, which might have weapons or military personnel on-board, would likely prove too risky for some countries unless they could first use classified capabilities to intercept the vessel's communications, observe it continuously over time in high resolution, or review what human sources have said about its equipment, mission, and security posture.[87] In sum, some participating nations may decline to conduct law enforcement operations if they must rely solely upon IPMDA-passed information rather than higher fidelity classified intelligence.

## Conclusion

CSBA's Deterrence by Detection concept recommends combining commercial space-based collection with other ISR sources for a reason. If reliant solely on commercial collection, IPMDA will likely fall short of meeting Indo-Pacific nations' information needs regarding antagonistic Chinese maritime activity and other regional security threats. That said, IPMDA has pooled power and cultivated capability that Quad leaders can direct to worthy purposes in the years ahead. The next chapter demonstrates how integrating UAS into IPMDA would improve the initiative's ability to collect information in a crucial regional hotspot: the South China Sea.

85 Robert Delaney and Mark Magnier, "U.S. Officials Call China's Actions in the South China Sea Unsafe and Increasing," *South China Morning Post*, July 27, 2022, https://www.scmp.com/news/world/united-states-canada/article/3186696/us-officials-call-chinas-actions-south-china-sea.

86 Gregory B. Poling et al., *Pulling Back the Curtain on China's Maritime Militia* (Washington, DC: CSIS, November 2021), p. VII, https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/211118_Poling_Maritime_Militia.pdf?VersionId=Y5iaJ4NT8eITSlAKTr.TWxtDHuLIq7wR.

87 Coast guard personnel often conduct operations without such high-quality intelligence, a testament to their professionalism and bravery.

CHAPTER 3

# Location, Location, Location: Optimal UAS Configurations for IPMDA Surveillance of the South China Sea

The overall success of the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA) likely depends on how it performs in the South China Sea (SCS). Although its mandate spans the Pacific Islands, Southeast Asia, and Indian Ocean, it faces no tougher test than the SCS, a conflict-rife area beset with territorial and resource disputes and other forms of maritime insecurity. If IPMDA performs poorly at monitoring these problems, trying though they may be, then its reputation will suffer and its political support could evaporate. Such a failure would amplify growing concerns about the Quad's ability to deliver public goods to Southeast Asian countries facing intense pressure from China.[88]

To help avoid that fate, this chapter presents a novel operational analysis demonstrating that furnishing IPMDA with unmanned aircraft systems (UAS) would improve surveillance of the SCS relative to relying solely on commercial space-based collection. The analysis first divides the SCS into a grid using latitude and longitude lines and assigns each box a weighted value based on assessed ISR collection importance. It then considers IPMDA's base case of commercial satellites collecting broadly but shallowly across the grid with a supplemental option of UAS collecting narrowly but deeply. It evaluates a fleet of three UAS in different configurations, varying the basing location (Guam and/or the Philippines), aircraft endurance (40-hour or 80-hour), and collection strategy (broad or targeted). Future

88 Cooper and Poling, "The Quad Goes to Sea."

research could use the same setup to analyze other areas, such as the Indian Ocean region, where India faces a growing challenge from China.[89]

The chapter finds that UAS greatly improve SCS surveillance relative to commercial satellites if the UAS adopt a targeted collection strategy of loitering longer in more important areas. The UAS configuration featuring Philippines-based, 40-hour endurance aircraft performs best according to most criteria, including after normalizing the results per collection hour. This finding reaffirms the commonsense notion that better basing enables better ISR collection in the vast Western Pacific theater. To borrow the saying from real estate, Indo-Pacific ISR aircraft operations are all about location, location, location. Despite its higher effectiveness, the best-performing UAS configuration fails to cover the grid's western half near Vietnam under the preferred targeted collection strategy. The configuration would require 14 aircraft, not the three aircraft used in the analysis, to survey the entire grid in one collection cycle (i.e., all aircraft simultaneously flying their full endurances).

These findings carry three implications about integrating UAS into IPMDA. First, IPMDA's most feasible option is combining collection by commercial satellites and UAS. Fielding over a dozen UAS in the Philippines to surveil the entire SCS grid in one collection cycle, as required under the best-performing configuration, likely would prove impractical politically and budgetarily for IPMDA. Second, IPMDA would improve its surveillance of the SCS by operating UAS from Vietnam. The failure of the best performing three-aircraft configuration to surveil important areas near Vietnam when conducting targeted collection indicates that Philippines basing is incredibly helpful, but alone insufficient, for maintaining comprehensive maritime domain awareness in the SCS. Third, if the Philippines or Vietnam proved unwilling or unable to host UAS, IPMDA would best utilize standoff-based long endurance UAS by operating them from Japan (Honshu), Northern Australia, Singapore, and/or Malaysia. These countries very roughly match Guam's standoff distance from the SCS, but their locations permit SCS-bound aircraft to fly past geopolitically significant areas such as Taiwan and Southeast Asia's maritime chokepoints.

## Research Background: Two Innovations Introduced by the Analysis

Recent studies have demonstrated how to optimize UAS collection routes given a geographic grid with values weighted by expected information gains.[90] The analysis follows the same basic approach but introduces two innovations to inform a policymaking readership and advance the literature.

89 Sameer Lalwani, "The Chinese Threat No One Is Talking About — And How to Counter It," *Politico Magazine*, March 16, 2022, https://www.politico.com/news/magazine/2022/03/16/india-china-indian-ocean-00017520.

90 Michael D. Moskal II and Rajan Batta, "A Macrogrid Approach for Routing UAVs in Support of Information Gathering," *Military Operations Research* 22, no. 4 (2017), pp. 35–54; and Michael D. Moskal II and Rajan Batta, "Adaptive Unmanned Aerial Vehicle Surveillance Using a Prize-Collecting Vertex Routing Model," *Military Operations Research* 24, no. 4 (2019), pp. 5–22.

First, the analysis examines a specific grid, the SCS, and assigns weighted values based on research and judgment, a widely used technique among ISR practitioners.[91] In contrast, recent studies have examined a generic grid and assigned weighted values by assumption, a more convenient setup conducive to optimization, the central focus of most operations research. The analysis thus contributes both an intelligence assessment of the most important SCS areas for ISR collection and an optimization solution for routing UAS to those areas. Recent studies presented only the latter and only in generic terms.

Second, the analysis identifies and solves a new variant of a well-known optimization problem, the team orienteering problem (TOP), contributing new knowledge applicable to future research. The TOP's name serves as a nod to the sport of orienteering's emphasis on navigation and efficient route planning, two factors of great importance to ISR operations.[92] Briefly, the TOP considers a problem in which groups traveling within a pre-designated area coordinate to visit checkpoints, earn associated points, and maximize their collective score before time expires. In our variant, which we call the team orienteering problem with prize-dependent loitering times (TOP-PDLT), groups must wait at each checkpoint for a penalty period that is proportional to the point value of the checkpoint.[93]

These two innovations are mutually reinforcing, with the collection assessment driving the route optimization, which in turn increases demand for additional assessment. This dynamic resembles how intelligence feeds operations and operations feed intelligence on well-functioning battle staffs.

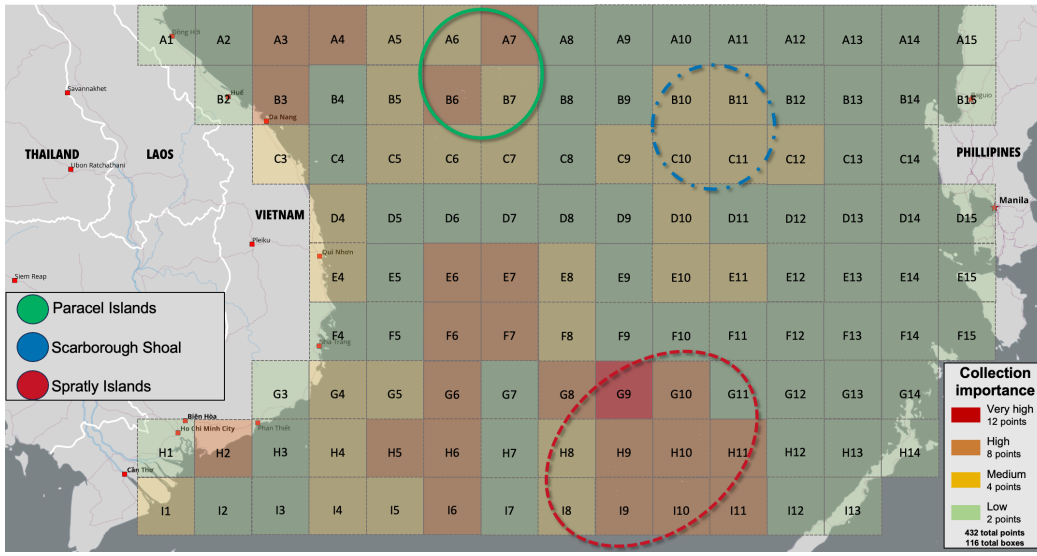
91 Terry A. Bresnick et al., "Airborne and Space-Borne Reconnaissance Force Mixes: A Decision Analysis Approach," *Military Operations Research* 3, no. 4 (1997), pp. 65–78; and Carl Rhodes, Jeff Hagen, and Mark Westergren, *A Strategies-to-Tasks Framework for Planning and Executing Intelligence, Surveillance, and Reconnaissance (ISR) Operations* (Santa Monica, CA: RAND Corporation, 2007), pp. 11–14, https://www.rand.org/content/dam/rand/pubs/technical_reports/2007/RAND_TR434.pdf.

92 The orienteering sport originated in Sweden in the 19th century and has since become popular in the United States, including within the U.S. military and Boy Scouts of America. Björn Kjellstrom, a Swedish-American ski orienteering champion and co-founder of the Silva Sweden AB compass manufacturing company, is often credited with popularizing the orienteering sport in the United States.

93 Tim Sadov and Travis Sharp, "A Prize-Dependent Loitering Time Approach to UAS Routing: Application to South China Sea Maritime Domain Awareness," working paper, May 2023.

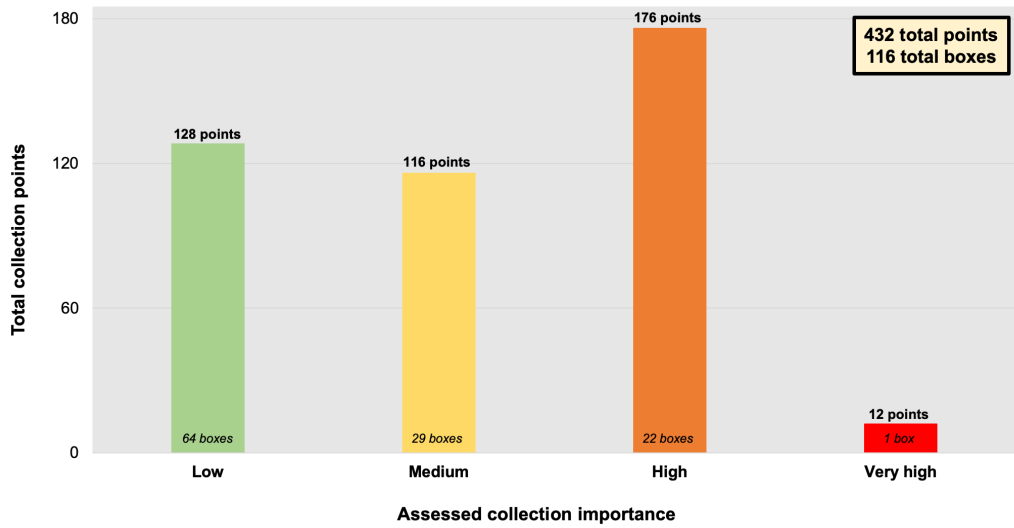
## Analysis Setup: South China Sea Geographic Grid with Weighted Values for Assessed ISR Collection Importance

### FIGURE 2: ASSESSED ISR COLLECTION IMPORTANCE OF THE SOUTH CHINA SEA GRID




**Source**: CSBA analysis of SeaVision AIS data.

### FIGURE 3: COLLECTION POINTS SUMMARY




**Source**: CSBA analysis of SeaVision AIS data.

The analysis's geographic grid covers a large section of the SCS lying between Vietnam and the Philippines running from 18° North to 9° North (**Figure 2**). The grid contains 116 boxes drawn along latitude and longitude lines with a total ocean area estimated at 375,000

square nautical miles (sq nm) – more than twice the size of California. The grid represents an important part of the SCS to study because it contains many disputed locations, including the Paracel Islands, Scarborough Shoal, and Spratly Islands. Each box's size generally corresponds with an ISR aircraft's sensor range. As a result, the analysis assumes that UAS flying near a box's center point can collect everywhere within that box.

Several examples support this assumption about UAS collection range. The grid's centermost box (E8) measures 60 nm (north-south) by 58 nm (west-east).[94] The MX-20 electro-optical/infrared imaging system integrated onto UAS such as the MQ-9 "can classify and identify a vessel at over 35 miles and read license plates at two miles," according to the manufacturer.[95] Additionally, the Scalable Open Architecture Reconnaissance (SOAR) SIGINT pod integrated onto the MQ-9 can identify, geolocate, and characterize radiofrequency signals to determine electronic order of battle at a range of over 200 nm.[96] Given these sensor ranges, a UAS positioned near box E8's center point could collect imagery and signals on vessels transiting throughout the box.[97]

The grid includes four ratings for ISR collection importance (low, medium, high, very high) with corresponding point values (2, 4, 8, 12) representing an assessment based on qualitative and quantitative factors as well as the authors' judgment. Each box's rating is a function of two sub-ratings – we call them trouble and traffic – reflecting geopolitical risk and vessel density, respectively, in the SCS.[98] Accordingly, each box's overall score represents the sum of its trouble score and its traffic score (see **Appendix** for each box's sub-rating scores). As with most scoring systems of this type, the point values themselves are arbitrary, but the differences between them illustrate assessed relative importance.[99] The analysis awards

94 Figures rounded to nearest whole unit. NOAA, "Latitude/Longitude Distance Calculator," accessed February 24, 2023, https://www.nhc.noaa.gov/gccalc.shtml.

95 General Atomics, "GA-ASI and L3Harris Technologies Successfully Integrate WESCAM MX-20 onto MQ-9," March 4, 2020, https://www.ga-asi.com/ga-asi-and-l3harris-technologies-successfully-integrate-wescam-mx-20-onto-mq-9; and Chris Pocock, "Wescam Is Taking Full Motion Video to New Levels of Quality," *AINonline*, July 8, 2012, https://www.ainonline.com/aviation-news/defense/2012-07-08/wescam-taking-full-motion-video-new-levels-quality. For an example of the MX-20's infrared imaging quality at roughly half the cited range of 35+ nm, see the 3:01 mark of L3 WESCAM, "MX-20 Product Video," *YouTube.com*, December 10, 2013, https://www.youtube.com/watch?v=jtYaejwd1Y0.

96 General Atomics, "The Multi-Domain Advantage: MQ-9B," 2022, p. 4, https://www.ga-asi.com/remotely-piloted-aircraft/pdf/multi-domain-mq-9b.pdf; Audrey Decker, "GA-ASI to Deliver Two MQ-9As to 3rd MRL in Hawaii Next Summer," *Inside Defense*, May 17, 2022; and L3Harris, "The New Option for Modern Threats – SOAR," April 2021, p. 3, https://www.l3harris.com/sites/default/files/2021-05/ims_rms_datasheet_mid_SOAR.pdf.

97 UAS could collect in box E8's corners, 42 nm from the center point, either by leveraging its EO-IR sensor's actual maximum performance (MX-20 range described as "*over* 35 miles") or by widening its search flight pattern around the center point (which in this case represents a geographic reference, not a collection target).

98 The sub-ratings focus on maritime domain awareness because that is IPMDA's mission. The sub-ratings do not focus on other potential missions for ISR collection such as obtaining indications and warning about an adversary's future military operations.

99 A classic study using this type of illustrative scoring system is Ashton B. Carter, "Assessing Command System Vulnerability," in Ashton B. Carter, John D. Steinbruner, and Charles A. Zraket, eds., *Managing Nuclear Operations* (Washington, DC: Brookings Institution, 1987), p. 567.

more points for high trouble scores than for high traffic scores because it assumes IPMDA will care most about higher-order regional security issues. Just over half the grid space is rated low with the rest possessing higher values (**Figure 3**).

The trouble sub-rating expresses whether a box featured one or more of the following geopolitical risk factors judged by the authors to be of utmost concern in the SCS:

1. Concentrated presence of China-flagged vessels (excluding port areas)
2. Concentrated presence of vessels broadcasting invalid AIS (excluding port areas)
3. Location with elevated likelihood of maritime boundary violations
4. Fishing hotspot
5. Major disputed territorial feature (Paracels, Scarborough, or Spratlys)

For the trouble sub-rating, the analysis scored boxes with zero factors as low (1 point), one factor as medium (3 points), two factors as high (7 points), and three factors as very high (11 points). To determine these scores, the analysis examined AIS data accessed through SeaVision, the Department of Transportation's unclassified online MDA platform used by U.S. allies and partners.[100] As an example, the box assessed to be the grid's most important collection area, G9, received a trouble sub-rating of very high (11 points) due to the concentrated presence of China-flagged vessels and vessels broadcasting invalid AIS near the disputed Spratly Islands.[101] Combining box G9's trouble sub-rating of 11 points with its traffic sub-rating of 1 point yields its overall score of 12 points.

The traffic sub-rating expresses whether a box contained an unusually large number of vessels and thus presented a special challenge for maritime domain awareness. To score this traffic factor, the analysis calculated vessel density using SeaVision's AIS data and then constructed a histogram to identify breaks in the data.[102] (See **Appendix** for histogram). The analysis scored the three outlier boxes identified by the histogram as medium (3 points,

100 The analysis identified Chinese-flagged vessels, vessels with invalid automatic identification system (AIS), and potential maritime boundary violation locations by activating SeaVision's exclusive economic zone (EEZ) static layer and examining AIS data filtered by:
- Data sources (deactivated simulated AIS and non-AIS);
- Vessel age (set maximum to 90 days [September 10–December 9, 2022]);
- AIS (activated anchored or underway [examined both] and flag China, Hong Kong, and Macao)
- Anomalous data (activated invalid maritime mobile service identity [MMSI] number and invalid International Maritime Organization [IMO] number).

Additionally, the analysis identified fishing hotspots by studying the historical heatmap static layer, filtered by fishing vessels, over an 11-month period (January-November 2022). For more information about SeaVision, see Department of Transportation, "Support," accessed March 1, 2023, https://info.seavision.volpe.dot.gov/support/.

101 Box G9 featured vessels broadcasting invalid AIS flagged to countries besides China, meaning the two risk factors did not completely overlap. The analysis addressed that concern when scoring all boxes.

102 The analysis examined SeaVision's AIS data using the same procedure described in the previous footnote except it did not filter by flag or anomalous data.

box C3) or high (5 points, boxes B3 and H2) and scored all other boxes as low (1 point), with "low" used here in the relative sense and to maintain semantic consistency. The three boxes receiving the medium and high traffic sub-ratings are located near the busy Vietnamese ports at Da Nang and Ho Chi Minh City.

Studying vessel density demonstrates the prevalence of both fishing activity and Vietnam-flagged vessels in the SCS. Any viable IPMDA surveillance plan for the SCS must deal appropriately with these factors. Fishing vessels appeared most often across the AIS data for all 116 boxes, accounting for 58 percent of all observations, followed by unknown vessels at 16 percent and cargo vessels at 10 percent. Vietnam-flagged vessels comprised most of the traffic, representing 87 percent of all observations, followed by China-flagged vessels at 3 percent and Panama-flagged vessels at 2 percent. Finally, fishing vessels showed up most often among China-flagged vessels, comprising 40 percent of that subgroup of observations.

## Base Case Analysis: Collection by Commercial Satellites

UAS equipped with the types of sensors mentioned in the preceding section can conduct more granular surveillance of important SCS collection areas than commercial space-based satellites. Two factors account for this advantage.

First, UAS can provide full motion video and other forms of high-resolution imagery continuously, whereas commercial satellites do not produce video and collect imagery only intermittently based on their revisit rates. Persistent high-resolution collection by UAS supports finer-grained intelligence assessments. For example, it allows analysts to assess whether crew members located on a vessel's topside are carrying weapons and thus might attack law enforcement personnel preparing to interdict the vessel.

Second, UAS equipped with multiple sensors, such as a camera and SIGINT pod, can independently find, fix, and track targets by correlating observations across different collection methods. For example, a UAS might use its SIGINT pod to detect a signal of interest, fly toward the assessed geolocation, and then use its camera to identify the vessel emitting the signal. A commercial satellite cannot perform this type of independent mixed-method collection in near real-time, although commercial firms have synthesized collection acquired separately to produce joint assessments of geopolitical events.[103]

To represent these qualitative differences, the analysis assumes that commercial satellites accumulate collection points broadly, shallowly, and intermittently across the entire SCS grid, accruing some points from all boxes each collection cycle. In contrast, UAS accumulate points narrowly, deeply, and continuously one box at a time by loitering for the length of time prescribed by the collection strategy. UAS then move on to visit other boxes until their fuel runs low and they return to base.

103 Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, p. 23.

These assumptions permit illustrative scoring of the base case. Imagine that a commercial satellite constellation produces one full set of panchromatic images of the entire SCS grid every 24-48 hours, a reasonable benchmark given current performance trends.[104] Next, assume that the images collected are sufficiently granular to earn one collection point from all 116 boxes.[105] Under these conditions, during each collection cycle of 24–48 hours, the satellite constellation would accumulate 116 collection points, equaling 27 percent of the grid's total points.[106]

Providing that level of ISR coverage would appreciably improve maritime domain awareness in the SCS, illustrating why IPMDA has rightly emphasized commercial collection's benefits. However, it would also leave a lot of points on the board. Supplementing commercial collection with UAS would allow IPMDA to peer deeper into potential problem areas.

## Supplemental Option Analysis: Collection by Unmanned Aircraft Systems

### Setup, Assumptions, and Method

To identify optimal UAS collection routes, the analysis incorporates assumptions based on previous research, unclassified aircraft attributes, and judgments about future policy choices. The analysis includes variables for basing location, aircraft endurance, and collection strategy to inform future decisions about how best to posture, develop, and employ ISR aircraft in the Indo-Pacific theater.

- **UAS fleet size**. The analysis evaluates a fleet of three UAS because that fleet size conforms with past CSBA research and appears feasible for IPMDA.[107]
- **Basing location (Guam and/or the Philippines)**. Guam basing exemplifies a scenario in which IPMDA decides (or is forced) to operate UAS from a Quad country's territory. Basing in the Philippines represents an SCS littoral nation agreeing to host UAS. The U.S.-Philippines basing access agreement announced in February 2023

104 NOAA, "Remote Sensing License Tiering," Q3 2022, p. 3; and Risa Haddal et al., "Detection via Persistence: Leveraging Commercial Imagery from Small Satellites," SAND2018-8105C, Office of Scientific and Technical Information, Department of Energy (2018), p. 6 of PDF, https://www.osti.gov/servlets/purl/1806743.

105 This assumption may be overly optimistic given that cloud cover and other environmental factors interfere with panchromatic collection during the daylight imaging window. However, recent advancements in commercial satellites' sensor offerings, constellation size, and revisit rates suggest that they will prove increasingly capable of performing high-quality, rapid-revisit collection under suboptimal conditions. Sandra Erwin, "Study: Space Industry Deploying More Satellites That Deliver Sharper Images," *SpaceNews*, January 16, 2023, https://spacenews.com/study-space-industry-deploying-more-satellites-that-deliver-sharper-images/.

106 The point accumulation could be higher or lower depending on assumptions about revisit rate and points-per-revisit. The point values represent the authors' assessment of expected information gains in this hypothetical scenario and should not be taken as conveying scientific or technical precision about satellite performance.

107 Mahnken, Sharp, and Kim, *Deterrence by Detection*, p. 32. The present analysis uses a three-aircraft fleet (vice four aircraft included in the earlier report) because it focuses on only one subarea of the SCS.

indicates this arrangement's plausibility.[108] The analysis uses Andersen Air Force Base on Guam and Clark Air Base in the Philippines as the assumed locations. The analysis includes one split configuration, with UAS based in both Guam and the Philippines, to illustrate an SCS littoral nation agreeing to provide only token support.

- **Aircraft endurance (40-hour or 80-hour)**. The analysis examines UAS rather than manned aircraft because it focuses on long endurance ISR operations. A 40-hour endurance UAS, flying at an assumed constant speed of 160 knots, approximates the capability offered by established long endurance UAS such as the MQ-9 and RQ-4.[109] An 80-hour endurance UAS, flying at an assumed constant speed of 80 knots, represents the notional capability offered by experimental super long endurance UAS such as the Orion and Ultra LEAP systems.[110] The analysis assumes that 80-hour endurance UAS would not operate from the Philippines due to the fear of revealing details about an advanced aircraft design.

- **Collection strategy (broad or targeted)**. The analysis assumes that UAS earn one collection point for every hour spent loitering in a box, a rate derived from common ISR planning practices.[111] During a collection cycle, defined as the three UAS simultaneously flying their full endurances, the analysis assumes a box can award its points one time to one UAS, meaning points do not replenish and multiple UAS cannot team up in one box.

    - Broad collection. A broad collection strategy requires UAS to loiter in each box for exactly one hour before proceeding to other boxes. Loiter time per box thus remains constant.[112] Under broad collection, UAS are incentivized to visit boxes based on point values even though UAS do not harvest all the points from more valuable boxes due to loitering for only one hour. ISR planners might use broad collection when they lack long endurance aircraft capable of prolonged loitering or need to survey a new (or changed) operating area to establish a baseline for collection importance.

108 Jim Gomez and Ellen Knickmeyer, "'A Big Deal': US, Philippines Tighten Military Ties," *AP*, February 2, 2023, https://apnews.com/article/taiwan-politics-united-states-government-ferdinand-marcos-jr-lloyd-austin-149f981290f849c62a684bea5d0d276b.

109 Janes, "GA-ASI Predator B/MQ – 9 Reaper/MQ-9B," *All the World's Aircraft: Unmanned*, November 21, 2022; and Janes, "Northrop Grumman RQ-4 Global Hawk," *All the World's Aircraft: Unmanned*, March 2, 2023.

110 Janes, "Aurora Flight Sciences Orion," *All the World's Aircraft: Unmanned*, December 2, 2022; and Air Force, "AFRL Completes Initial Ultra LEAP Flight Tests," December 15, 2019, https://www.af.mil/News/Article-Display/Article/2040071/afrl-completes-initial-ultra-leap-flight-tests/.

111 ISR practitioners commonly use time on target to measure the fulfillment of ISR collection requirements, with one hour being a standard planning factor. The analysis uses this rule of thumb for convenience but acknowledges its shortcomings. Future research could set a different relationship between box value and loitering time than the one included in our analysis. Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, p. 20.

112 Under broad collection, points earned and grids surveilled are equal, meaning the UAS collection rate of one point per box is the same as the satellite collection rate.

- Targeted collection. A targeted collection strategy requires UAS to loiter in each box for the number of hours equal to the box's collection points. UAS would loiter for eight hours in a box worth eight points before traveling to other boxes. Loiter time per box therefore varies, reflecting ISR planning practices of spending a few hours on routine targets but perhaps a full sortie (or multiple sorties) on high-value targets. UAS are incentivized to visit boxes based on point values but, unlike under broad collection, accrue all the points from each box they visit by loitering for the prescribed length of time. ISR planners might use targeted collection when they possess long endurance aircraft or need to monitor a crisis or illicit interaction continuously without interruption.

The analysis focuses on four configurations of basing and endurance encapsulating the range of important factors that IPMDA would likely consider when planning UAS operations. Using the assumed three-aircraft fleet, the analysis studies the following configurations:

- 3x Guam-based 40-hour UAS
- 3x Guam-based 80-hour UAS
- 2x Guam-based 40-hour UAS + 1x Philippines-based 40-hour UAS
- 3x Philippines-based 40-hour UAS

The authors wrote a program using Google's "OR-Tools" application programming interface (API) for Python 3.11.1 to identify optimal UAS collection routes, using as a model the team orienteering problem with prize-dependent loitering times described above.[113] The program read in a data file containing coordinates for the UAS basing locations and box center points as well as point values associated with each box. After calculating pairwise Haversine distances and defining the loitering constraint, the program executed the "cheapest arc path" first solution strategy to generate inputs to the simulated annealing process that returned the solutions.

113 Sadov and Sharp, "A Prize-Dependent Loitering Time Approach."

## Findings

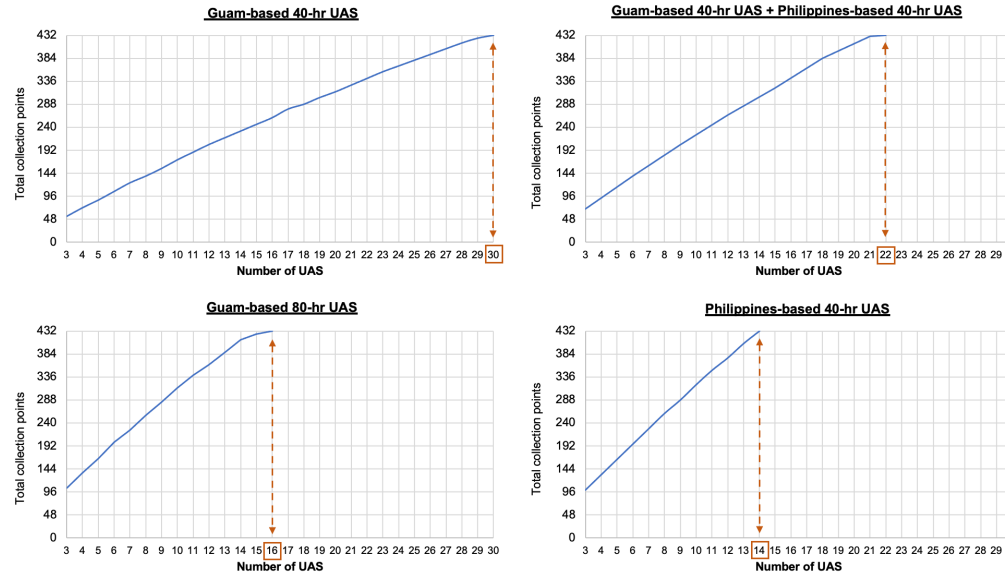
### TABLE 2: ISR COLLECTION PERFORMANCE OF FOUR UAS CONFIGURATIONS

| = best result | Broad collection results | Targeted collection results | Improvement under targeted collection vs. base case | Points per hour under targeted collection | UAS needed to surveil entire grid in one targeted collection cycle |
|---|---|---|---|---|---|
| **3x Guam-based 40-hr UAS**<br>40-hr collection cycle | 38 of 432 pts<br>38 boxes surveilled | 54 of 432 pts<br>21 boxes surveilled | 28% | 1.35 | 30 |
| **3x Guam-based 80-hr UAS**<br>80-hr collection cycle | 68 of 432 pts<br>68 boxes surveilled | 104 of 432 pts<br>24 boxes surveilled | 69% | 1.3 | 16 |
| **2x Guam-based 40-hr UAS + 1x Philippines-based 40-hr UAS**<br>40-hr collection cycle | 50 of 432 pts<br>50 boxes surveilled | 70 of 432 pts<br>19 boxes surveilled | 44% | 1.75 | 22 |
| **3x Philippines-based 40-hr UAS**<br>40-hr collection cycle | 79 of 432 pts<br>79 boxes surveilled | 102 of 432 pts<br>20 boxes surveilled | 71% | 2.55 | 14 |
| **Base case (commercial satellites)**<br>24-48-hr collection cycle | 116 of 432 pts<br>116 boxes surveilled | Not applicable | Not applicable | 2.4 (48-hr cycle)<br>4.8 (24-hr cycle) | Not applicable |

**Source**: CSBA analysis using Google's OR-Tools API for Python 3.11.1.

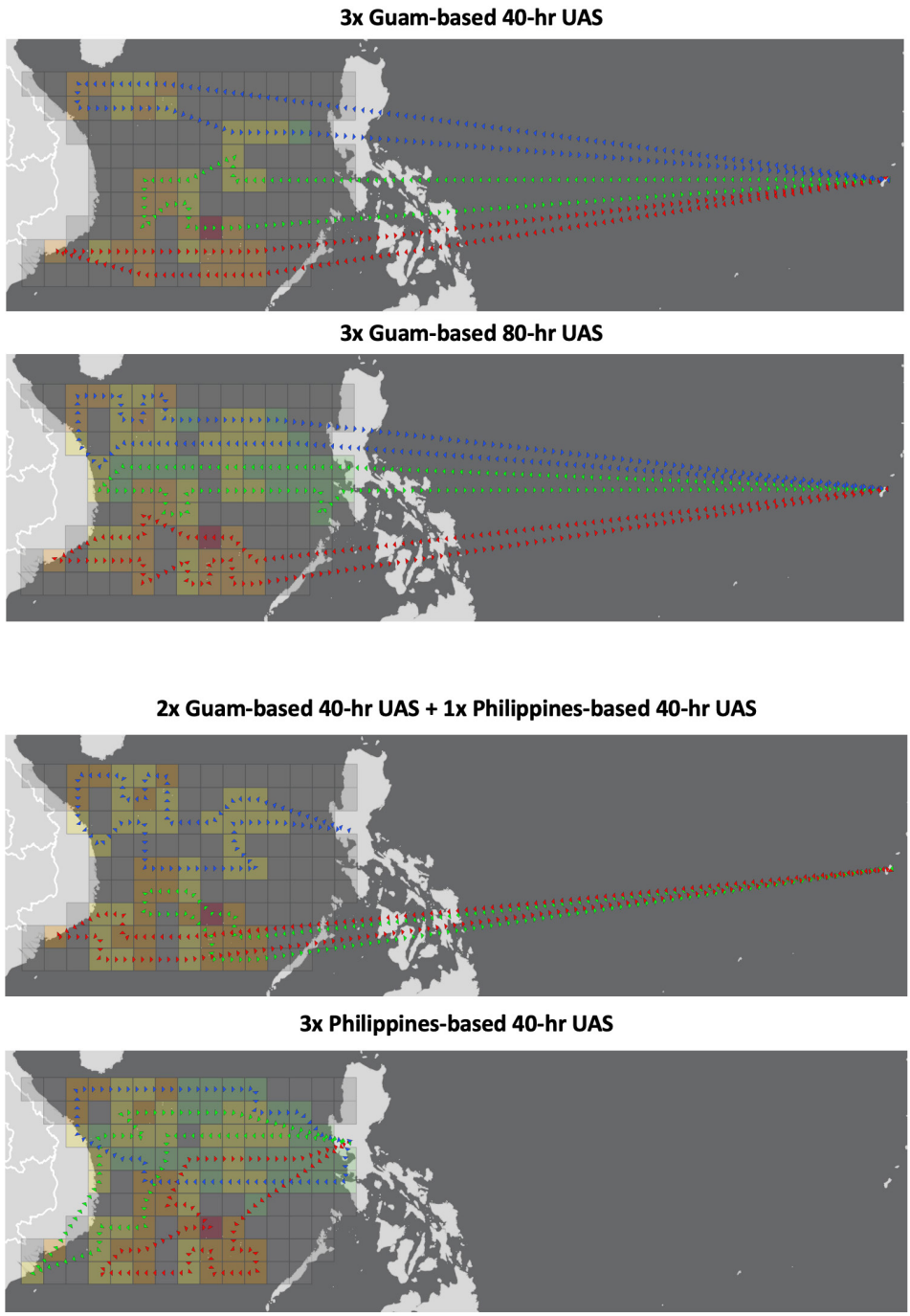
**Notes**: The "improvement over base case" calculations first subtract out the overlapping points collected by both UAS and satellites (one point per box surveilled, equaling the satellites' assumed collection rate) and then add the result to the base case's accumulation (116 points) before computing the percentage change. For each configuration, the calculation simplifies to (UAS total points – UAS grids visited) / 116 = % change. The "points per hour" calculations divide the targeted collection points by the collection cycle hours.

### FIGURE 4: UAS FLEET SIZES REQUIRED TO SURVEIL ENTIRE GRID IN ONE CYCLE OF TARGETED COLLECTION




**Source**: CSBA analysis using Google's OR-Tools API for Python 3.11.1.

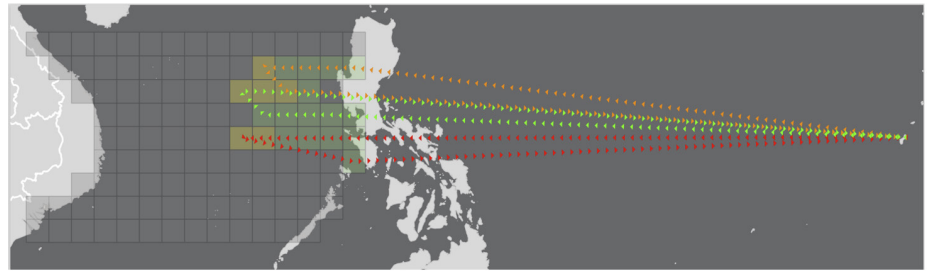
## FIGURE 5: OPTIMAL ROUTES AND GEOGRAPHIC COVERAGES UNDER BROAD COLLECTION



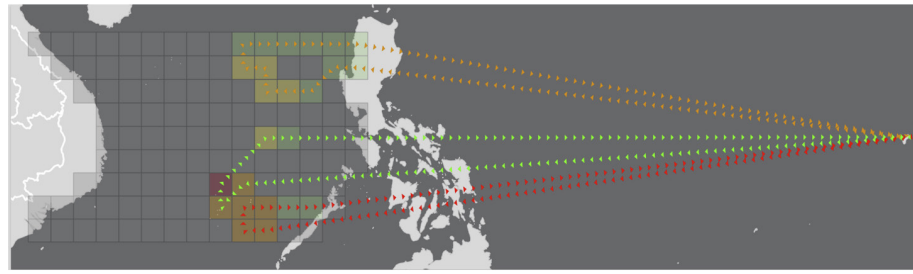

**Source**: CSBA analysis using Google's OR-Tools API for Python 3.11.1.

## FIGURE 6: OPTIMAL ROUTES AND GEOGRAPHIC COVERAGES UNDER TARGETED COLLECTION

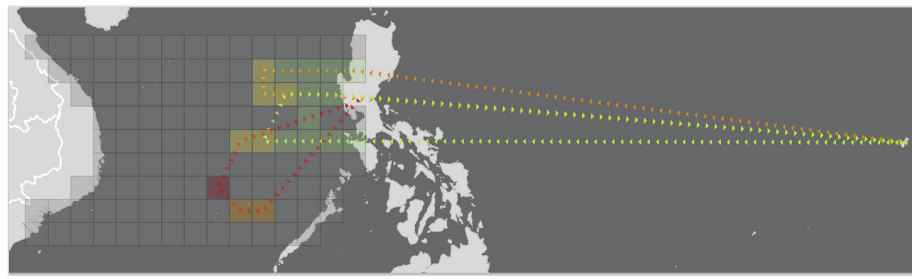
**3x Guam-based 40-hr UAS**



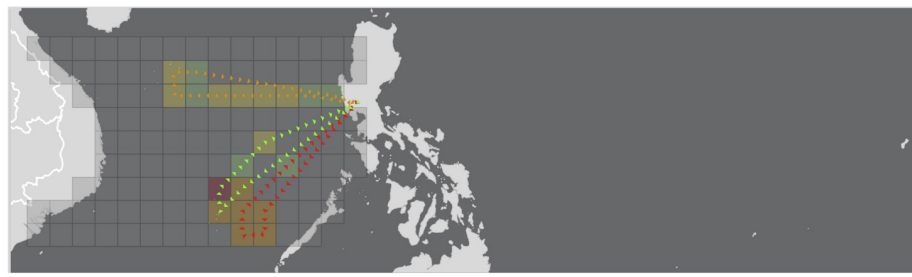
**3x Guam-based 80-hr UAS**



**2x Guam-based 40-hr UAS + 1x Philippines-based 40-hr UAS**



**3x Philippines-based 40-hr UAS**



**Source**: CSBA analysis using Google's OR-Tools API for Python 3.11.1.

**Table 2** summarizes how the four UAS configurations perform under each collection strategy, with the commercial satellite base case included for reference. **Figure 4** plots the UAS fleet sizes required to surveil the entire grid in one targeted collection cycle. **Figure 5** and **Figure 6** illustrate the optimal routes and geographic coverages for the three-aircraft UAS configurations under each collection strategy.[114]

Five main findings flow from these results. First, targeted collection outperforms broad collection under all UAS configurations. By restricting UAS from capitalizing on perhaps their greatest strength, persistent loitering, broad collection forfeits much of the advantage offered by UAS. Targeted collection, on the other hand, enables UAS to gather points that commercial satellites would not attain otherwise. Relative to the base case, targeted collection by UAS increases total point accumulation per collection cycle by between 28 percent and 71 percent. Overall, UAS performing targeted collection deliver deeper surveillance of important SCS areas than commercial satellites alone, supporting the report's central argument.

Second, the configuration featuring Philippines-based, 40-hour endurance UAS outperforms the alternatives according to most criteria, including after normalizing the results to points per hour. This finding supports the intuitive principle that better basing enables better ISR collection in the expansive Indo-Pacific region. The configuration featuring Guam-based, 80-hour endurance UAS earns the most points under targeted collection, but it has a longer-duration collection cycle. If 40-hour UAS flew more than one sortie every 80 hours, on average, then they would collect more than the 80-hour UAS. However, if ISR planners determined that back-to-back sorties by 40-hour UAS were unsustainable or unnecessary, then the 80-hour UAS would present an effective option.

Third, the configurations would require between 14 and 30 UAS to surveil the entire grid in one targeted collection cycle, whereby all aircraft simultaneously fly their full endurances. Fielding UAS fleets of that size likely would prove unworkable for IPMDA. However, using UAS as a supplement to commercial space-based collection would eliminate the need to operate so many aircraft. Combining broad collection by commercial satellites with targeted collection by UAS provides a middle-ground option that should prove both more effective than commercial satellites alone and more feasible than UAS alone. As noted in Chapter 4, a contractor-owned, contractor-operated fleet of three UAS would cost IPMDA approximately $50 million per year, an expense that could be split among those Quad members and participating countries willing to contribute.

Fourth, under the preferred targeted collection strategy, all configurations fail to surveil the grid's western half near Vietnam, including the important areas around the Paracel Islands. Operating additional UAS from Vietnam presents one way to reach these important collection areas. The most promising Vietnamese bases include Da Nang in central Vietnam and

114 The analysis assumes that IPMDA-operated UAS have permission to overfly the Philippines.

Nha Trang, Cam Ranh, or Phan Rang in south central Vietnam due to their proximity to important ISR collection areas. Vietnam has a strong incentive to support UAS surveillance by IPMDA given that Vietnam-flagged vessels comprised nearly 90 percent of the AIS vessel observations in the SCS grid examined by the analysis.

Fifth, Guam-based UAS spend significant time flying over open ocean before they reach the SCS, limiting the opportunity for collateral collection en route (known as "non-interference basis" or NIB collection). If standoff-based aircraft instead operated from Japan (Honshu), Northern Australia, Singapore, or Malaysia – countries very roughly matching Guam's standoff distance from the SCS – then they could perform some collection over geopolitically significant areas such as Taiwan and Southeast Asia's maritime chokepoints during their flights to the SCS. UAS operating from the four countries could perform NIB collection while flying to and from the SCS, increasing each sortie's return on investment and delivering valuable collection to countries beyond the SCS grid examined in the analysis. Existing airfields in the four countries offer feasible locations for basing UAS.

## Conclusion

This chapter demonstrated that UAS would improve IPMDA's surveillance of important SCS areas. It did not examine the organizational, logistical, and political arrangements required for IPMDA to operate UAS.[115] It avoided those issues largely because insufficient public details exist about IPMDA's inner workings to produce a rigorous assessment. That said, a proven and flexible solution already exists for fielding UAS to perform new missions: contractor-owned, contractor-operated (COCO) aircraft. The final chapter briefly describes how IPMDA could take advantage of COCO UAS to improve surveillance in the Western Pacific and beyond.

115 Organizational and logistical issues would include burden sharing, information security, data processing and dissemination, command and control, mission planning, and other issues. Previous CSBA research has addressed some of these considerations in a multi-national setting. Mahnken, Sharp, Bassler, and Durkee, *Implementing Deterrence by Detection*, pp. 31–36.

CHAPTER 4

# Conclusion: Advancing Deterrence by Detection by Furnishing IPMDA with Contractor-Owned, Contractor-Operated UAS

The creation of the Indo-Pacific Partnership for Maritime Domain Awareness (IPMDA) presents a new opportunity for the United States and its allies to advance Deterrence by Detection. This report argued that furnishing IPMDA with unmanned aircraft systems (UAS) would greatly improve its ability to surveil critical areas such as the South China Sea. Supplementing commercial geospatial collection with a modestly sized UAS fleet represents an effective and feasible approach for IPMDA.

One promising option for quickly fielding UAS to support IPMDA would involve using contractor-owned, contractor-operated (COCO) aircraft. Leasing COCO aircraft would make UAS affordable to states that might otherwise lack the resources to procure and maintain such aircraft. It would make capabilities available to states that might otherwise have difficulty gaining approval to purchase the aircraft. COCO aircraft could be operational in a few months rather than the several years it often takes to complete aircraft sales. Leasing COCO aircraft grants countries room to grow operationally. As U.S policy and partner budgets permit, states can move from COCO to leased aircraft, to lease-to-own aircraft, to purchased aircraft while retaining operational capability and increasing proficiency.

The Quad countries have taken advantage of the flexibility offered by COCO aircraft. India has MQ-9A COCO aircraft flying in the Indian Ocean and is purchasing the MQ-9B.[116] It is not alone. Australia, Great Britain, and Japan are all procuring MQ-9Bs while Australia is also buying the MQ-4C Triton and Japan is acquiring the RQ-4 Block 30.[117] Once these countries take delivery of the aircraft, they can work with other Indo-Pacific partners on various operational procedures, including the processing, exploitation, and dissemination of data representing perhaps the most critical aspect of ISR operations.

A COCO fleet of three UAS, matching the fleet size analyzed in Chapter 3, would cost IPMDA approximately $50 million annually according to CSBA analysis of industry data.[118] A multi-country COCO approach would benefit IPMDA by decreasing costs per country while promoting multinational cooperation. If the four Quad countries split the bill evenly, they would each pay $12.5 million per year. Splitting the cost five ways by including the Philippines would lower the contribution to $10 million, while adding Vietnam would drop it further to $8.3 million, although the Quad would almost surely pay these two countries' shares if they permitted UAS to operate from their territory. Of course, India might prove unwilling to contribute financially to UAS operations in the South China Sea. However, the point here is that multiple countries could split the cost of the UAS.

IPMDA could begin implementing the concepts outlined in this report right away if the Quad invested in standing up a small fleet of COCO UAS. Political support for conducting Deterrence by Detection-style ISR operations has grown in Washington and the Indo-Pacific region, but the window of opportunity to act may not last long. Policymakers should not delay in taking practical steps to ward off the growing dangers to regional security posed by China and other malicious actors.

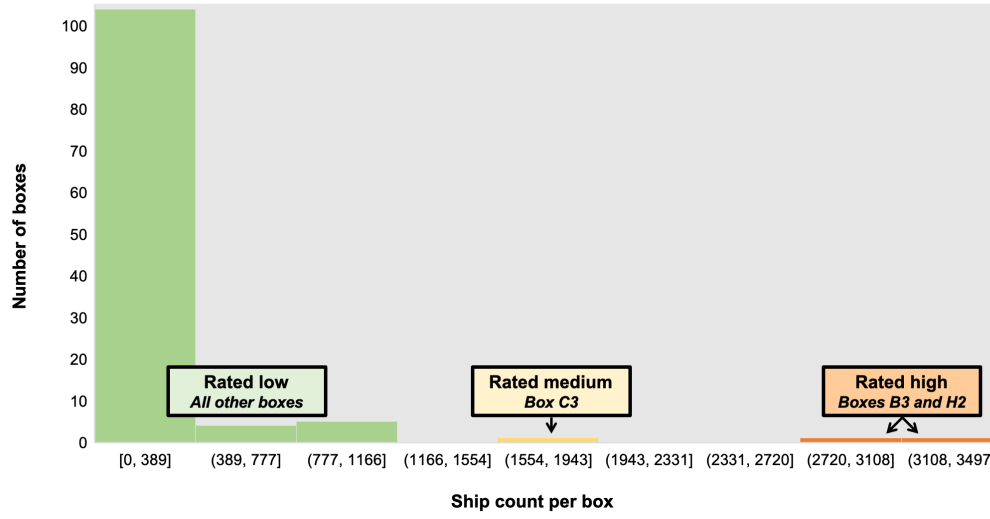
116 Shishir Gupta, "Indian Military Pares Down Its Predator Drone Requirement to 18 from 30," *Hindustan Times*, April 13, 2023, https://www.hindustantimes.com/india-news/indian-military-pares-down-its-predator-drone-requirement-to-18-from-30-101681359910536.html.

117 Janes, "GA-ASI Predator B/MQ – 9 Reaper/MQ-9B,"; and Janes, "Northrop Grumman RQ-4 Global Hawk."

118 The costs would be higher if additional UAS were fielded to ensure that three UAS were always available.

# Appendix

## FIGURE 7: AIS SHIP COUNT HISTOGRAM USED FOR TRAFFIC SUB-RATING




**Source**: CSBA analysis of SeaVision AIS data.

**Notes**: The analysis used Doane's formula for non-normal distributions to determine the number of histogram bins. P.A. Legg et al., "Improving Accuracy and Efficiency of Mutual Information for Multi-Modal Retinal Image Registration Using Adaptive Probability Density Estimation," *Computerized Medical Imaging and Graphics* 37, nos. 7-8 (October-December 2013), p. 600; and David P. Doane, "Aesthetic Frequency Classifications," *The American Statistician* 30, no. 4 (November 1976), pp. 181–183.

## TABLE 3: TROUBLE AND TRAFFIC SUB-RATINGS FOR SOUTH CHINA SEA GRID

| box_id | trouble_rating | trouble_points | traffic_rating | traffic_points | overall_rating | overall_points |
|---|---|---|---|---|---|---|
| **a1** | low | 1 | low | 1 | low | 2 |
| **a2** | low | 1 | low | 1 | low | 2 |
| **a3** | high | 7 | low | 1 | high | 8 |
| **a4** | high | 7 | low | 1 | high | 8 |
| **a5** | medium | 3 | low | 1 | medium | 4 |
| **a6** | medium | 3 | low | 1 | medium | 4 |
| **a7** | high | 7 | low | 1 | high | 8 |
| **a8** | low | 1 | low | 1 | low | 2 |
| **a9** | low | 1 | low | 1 | low | 2 |
| **a10** | low | 1 | low | 1 | low | 2 |
| **a11** | low | 1 | low | 1 | low | 2 |
| **a12** | low | 1 | low | 1 | low | 2 |
| **a13** | low | 1 | low | 1 | low | 2 |
| **a14** | low | 1 | low | 1 | low | 2 |
| **a15** | low | 1 | low | 1 | low | 2 |
| **b2** | low | 1 | low | 1 | low | 2 |
| **b3** | medium | 3 | high | 5 | high | 8 |
| **b4** | low | 1 | low | 1 | low | 2 |
| **b5** | medium | 3 | low | 1 | medium | 4 |
| **b6** | high | 7 | low | 1 | high | 8 |
| **b7** | medium | 3 | low | 1 | medium | 4 |
| **b8** | low | 1 | low | 1 | low | 2 |
| **b9** | low | 1 | low | 1 | low | 2 |
| **b10** | medium | 3 | low | 1 | medium | 4 |
| **b11** | medium | 3 | low | 1 | medium | 4 |
| **b12** | low | 1 | low | 1 | low | 2 |
| **b13** | low | 1 | low | 1 | low | 2 |
| **b14** | low | 1 | low | 1 | low | 2 |
| **b15** | low | 1 | low | 1 | low | 2 |
| **c3** | low | 1 | medium | 3 | medium | 4 |
| **c4** | low | 1 | low | 1 | low | 2 |
| **c5** | medium | 3 | low | 1 | medium | 4 |
| **c6** | medium | 3 | low | 1 | medium | 4 |
| **c7** | medium | 3 | low | 1 | medium | 4 |
| **c8** | low | 1 | low | 1 | low | 2 |
| **c9** | medium | 3 | low | 1 | medium | 4 |
| **c10** | medium | 3 | low | 1 | medium | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **c11** | medium | 3 | low | 1 | medium | 4 |
| **c12** | medium | 3 | low | 1 | medium | 4 |
| **c13** | low | 1 | low | 1 | low | 2 |
| **c14** | low | 1 | low | 1 | low | 2 |
| **d4** | medium | 3 | low | 1 | medium | 4 |
| **d5** | low | 1 | low | 1 | low | 2 |
| **d6** | low | 1 | low | 1 | low | 2 |
| **d7** | low | 1 | low | 1 | low | 2 |
| **d8** | low | 1 | low | 1 | low | 2 |
| **d9** | low | 1 | low | 1 | low | 2 |
| **d10** | medium | 3 | low | 1 | medium | 4 |
| **d11** | low | 1 | low | 1 | low | 2 |
| **d12** | low | 1 | low | 1 | low | 2 |
| **d13** | low | 1 | low | 1 | low | 2 |
| **d14** | low | 1 | low | 1 | low | 2 |
| **d15** | low | 1 | low | 1 | low | 2 |
| **e4** | medium | 3 | low | 1 | medium | 4 |
| **e5** | low | 1 | low | 1 | low | 2 |
| **e6** | high | 7 | low | 1 | high | 8 |
| **e7** | high | 7 | low | 1 | high | 8 |
| **e8** | medium | 3 | low | 1 | medium | 4 |
| **e9** | low | 1 | low | 1 | low | 2 |
| **e10** | medium | 3 | low | 1 | medium | 4 |
| **e11** | medium | 3 | low | 1 | medium | 4 |
| **e12** | low | 1 | low | 1 | low | 2 |
| **e13** | low | 1 | low | 1 | low | 2 |
| **e14** | low | 1 | low | 1 | low | 2 |
| **e15** | low | 1 | low | 1 | low | 2 |
| **f4** | low | 1 | low | 1 | low | 2 |
| **f5** | low | 1 | low | 1 | low | 2 |
| **f6** | high | 7 | low | 1 | high | 8 |
| **f7** | high | 7 | low | 1 | high | 8 |
| **f8** | medium | 3 | low | 1 | medium | 4 |
| **f9** | low | 1 | low | 1 | low | 2 |
| **f10** | low | 1 | low | 1 | low | 2 |
| **f11** | low | 1 | low | 1 | low | 2 |
| **f12** | low | 1 | low | 1 | low | 2 |
| **f13** | low | 1 | low | 1 | low | 2 |
| **f14** | low | 1 | low | 1 | low | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **f15** | low | 1 | low | 1 | low | 2 |
| **g3** | low | 1 | low | 1 | low | 2 |
| **g4** | medium | 3 | low | 1 | medium | 4 |
| **g5** | medium | 3 | low | 1 | medium | 4 |
| **g6** | high | 7 | low | 1 | high | 8 |
| **g7** | low | 1 | low | 1 | low | 2 |
| **g8** | high | 7 | low | 1 | high | 8 |
| **g9** | very high | 11 | low | 1 | very high | 12 |
| **g10** | high | 7 | low | 1 | high | 8 |
| **g11** | low | 1 | low | 1 | low | 2 |
| **g12** | low | 1 | low | 1 | low | 2 |
| **g13** | low | 1 | low | 1 | low | 2 |
| **g14** | low | 1 | low | 1 | low | 2 |
| **h1** | low | 1 | low | 1 | low | 2 |
| **h2** | medium | 3 | high | 5 | high | 8 |
| **h3** | low | 1 | low | 1 | low | 2 |
| **h4** | medium | 3 | low | 1 | medium | 4 |
| **h5** | high | 7 | low | 1 | high | 8 |
| **h6** | high | 7 | low | 1 | high | 8 |
| **h7** | low | 1 | low | 1 | low | 2 |
| **h8** | medium | 3 | low | 1 | medium | 4 |
| **h9** | high | 7 | low | 1 | high | 8 |
| **h10** | high | 7 | low | 1 | high | 8 |
| **h11** | high | 7 | low | 1 | high | 8 |
| **h12** | low | 1 | low | 1 | low | 2 |
| **h13** | low | 1 | low | 1 | low | 2 |
| **h14** | low | 1 | low | 1 | low | 2 |
| **i1** | medium | 3 | low | 1 | medium | 4 |
| **i2** | low | 1 | low | 1 | low | 2 |
| **i3** | low | 1 | low | 1 | low | 2 |
| **i4** | medium | 3 | low | 1 | medium | 4 |
| **i5** | medium | 3 | low | 1 | medium | 4 |
| **i6** | high | 7 | low | 1 | high | 8 |
| **i7** | low | 1 | low | 1 | low | 2 |
| **i8** | medium | 3 | low | 1 | medium | 4 |
| **i9** | high | 7 | low | 1 | high | 8 |
| **i10** | high | 7 | low | 1 | high | 8 |
| **i11** | high | 7 | low | 1 | high | 8 |
| **i12** | low | 1 | low | 1 | low | 2 |
| **i13** | low | 1 | low | 1 | low | 2 |

## LIST OF ACRONYMS

| | |
|---|---|
| **ABI** | activity-based intelligence |
| **AI** | artificial intelligence |
| **AIS** | automatic identification system |
| **API** | application programming interface |
| **COCO** | contractor-owned, contractor-operated |
| **CSBA** | Center for Strategic and Budgetary Assessments |
| **CSIS** | Center for Strategic and International Studies |
| **DoD** | Department of Defense |
| **EEZ** | exclusive economic zone |
| **FY** | fiscal year |
| **FDO** | foreign disclosure officer |
| **GEOINT** | geospatial intelligence |
| **IMO** | International Maritime Organization |
| **IPMDA** | Indo-Pacific Partnership for Maritime Domain Awareness |
| **ISR** | intelligence, surveillance, and reconnaissance |
| **JMSDF** | Japan Maritime Self-Defense Force |
| **ML** | machine learning |
| **MMSI** | maritime mobile service identity |
| **NIB** | non-interference basis |
| **NGA** | National Geospatial-Intelligence Agency |
| **nm** | nautical mile |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **RAND** | Research and Development Corporation |
| **RF** | radiofrequency |
| **SAR** | synthetic aperture radar |
| **SCS** | South China Sea |
| **SIGINT** | signals intelligence |
| **SOAR** | Scalable Open Architecture Reconnaissance |
| **sq** | square |
| **TOP** | team orienteering problem |
| **TOP-PDLT** | team orienteering problem with prize-dependent loitering times |
| **UAS** | unmanned aircraft systems |

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