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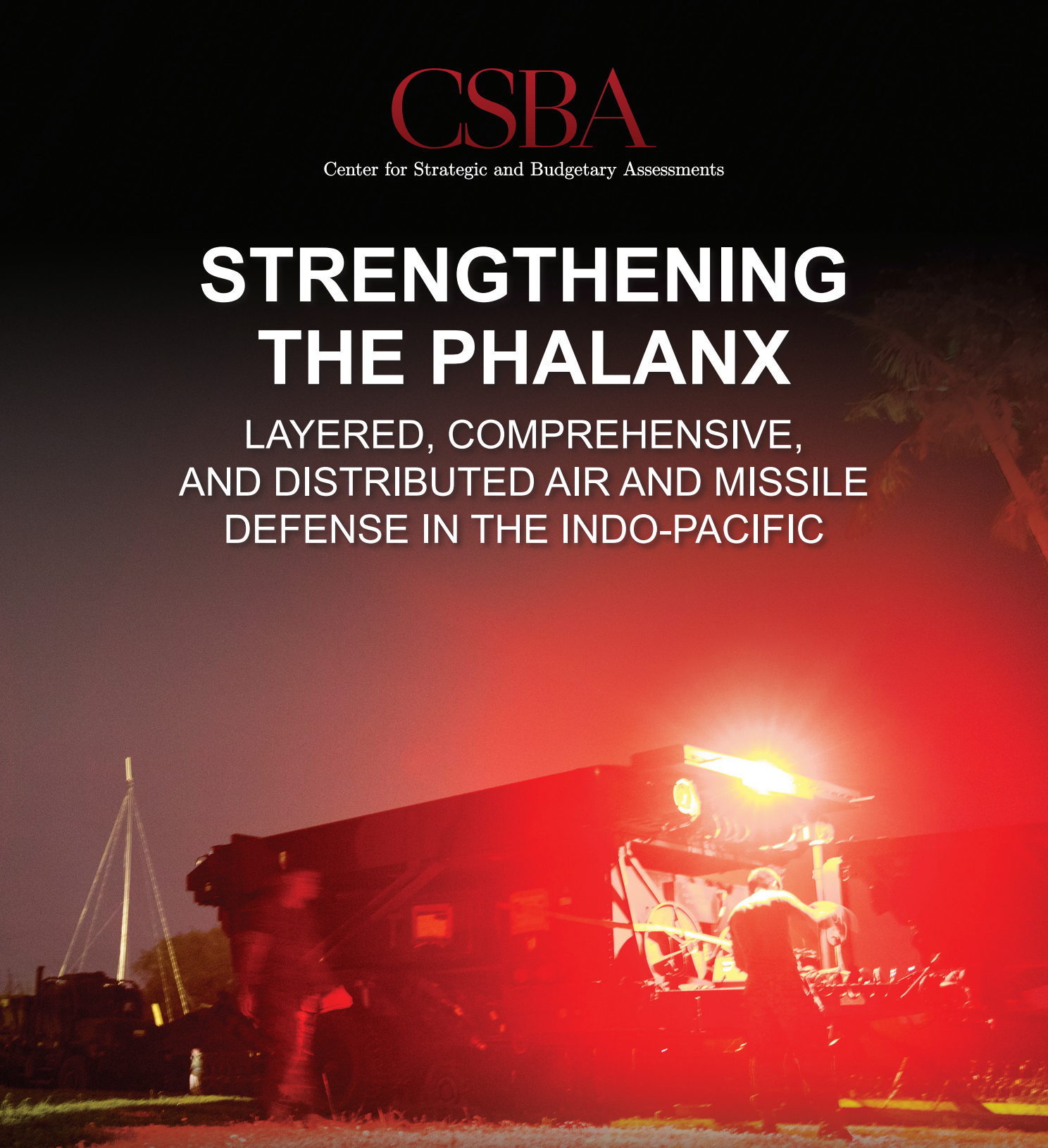
STRENGTHENING THE PHALANX

LAYERED, COMPREHENSIVE, AND DISTRIBUTED AIR AND MISSILE DEFENSE IN THE INDO-PACIFIC



CARL REHBERG

HERBERT KEMP

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Cover Graphic: Marines set up a radar in a field during Pacific Iron at Andersen Air Force Base, Guam, July 25, 2021. Photo by Marine Corps Lance Corporal Tyler Harmon.

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Executive Summary

One of the most critical operational challenges the United States is likely to confront in a future conflict, particularly in the Indo-Pacific theater, is the threat of massed precision-guided air and missile attacks on overseas ports, bases, and other vital facilities. DoD has invested significant resources to defend against ballistic missile attacks on the United States, as well as its forward bases and forward-operating forces.[1] However, it cannot still defeat large numbers of ballistic missiles, cruise missiles, and unmanned aerial systems (UAS).[2]

In general, IAMD is defined as "the integration of capabilities and overlapping operations" for "negating an enemy's ability to create adverse effects from air and missile capabilities" and includes three main elements: Offensive Counterair (OCA) attack operations, active air and missile defense, and passive air and missile defense (hereafter attack operations, active defenses, and passive defenses, respectively).[3] This report focuses on active defenses and examines the requirements for layered, comprehensive, and distributed IAMD capabilities, given the combination of rising threats to U.S. forces and the declining relevance of existing operational concepts for defense against those threats. Effective IAMD is a requirement to successfully withstand large initial attacks on U.S. and allied forces and territory, recover the initiative, and subsequently establish the conditions needed to achieve an acceptable end to hostilities.

1 Carl Rehberg and Mark Gunzinger, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases*. Washington, DC: Center for Strategic and Budgetary Assessments (CSBA), 2018, https://csbaonline.org/research/publications/air-and-missile-defense-at-a-crossroads-new-concepts-and-technologies-to-de.

2 See Carl Rehberg and Josh Chang, *Moving Pieces: Near-Term Changes to Pacific Air Posture*. Washington, DC: Center for Strategic and Budgetary Assessments (CSBA), 2022, https://csbaonline.org/research/publications/moving-pieces-near-term-changes-to-pacific-air-posture.

3 Joint Chiefs of Staff, "Joint Publication 3-01: Countering Air and Missile Threats," April 21, 2017, pp. I-10, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf.

The Salvo Threat from China

China has steadfastly built the capacity to influence air and sea control over First Island Chain nations. China has done this primarily by developing and deploying air-, land- and sea-based ballistic and cruise missiles with new threats emerging (e.g., hypersonic missiles, Hypersonic Glide Vehicles (HGVs), UAS). China's existing mobile offensive missiles have the range and the numbers to conduct ballistic and cruise missile attacks against all or part of the sovereign territories of the First Island Chain nations.

The Second Island Chain is anchored by the U.S. territory of Guam, which lies approximately 3,000 km east of China. Guam is home to Naval Base Guam and Andersen Air Force Base (AAFB). Because of Guam's strategic importance, it could be a lucrative target for air and missile attacks in the event of hostilities between the United States and China. A future Chinese attack on Guam could include cruise missiles, ballistic missiles, hypervelocity glide vehicles (HGVs), and UAS launched on widely varying trajectories from different azimuths around Guam.

Current Theater Active Air and Missile Defenses

One way to assess the status of active defenses is by critical organizations: the Missile Defense Agency (MDA), Navy, Army, Marine Corps, Air Force, Space Force, Joint Integrated Air and Missile Defense Organization (JIAMDO), and the Joint Counter-small Unmanned Aircraft Systems Office (JCO). The MDA is responsible for developing a layered Ballistic Missile Defense System for the DoD that includes capabilities to intercept ballistic missiles in their boost, midcourse, and terminal phases of flight. A more recent initiative has been the development of elements of a hypersonic missile defense system to defend against hypersonic weapons and other emerging missile threats. MDA's current approach, begun in April 2021, is to initiate the Glide Phase Interceptor (GPI) and integrate it with the Aegis system, with an initial target timeframe of the mid-2020s—now slipping into the early 2030s.

The U.S. Navy possesses the most developed layered, comprehensive, and distributed (due to ship mobility) IAMD of all services. The Navy's surface combatants both possess self-defense capabilities as well as constituting the sea-based leg of MDA's efforts for ballistic missile defense. The Navy's IAMD systems and missiles and other ship systems provide a layered and comprehensive IAMD for ballistic missiles, cruise missiles, and various air threats. Critical Navy IAMD systems are leveraged for the Guam Defense System.

DoD largely depends on the Army to organize, train, and equip its forces to provide land-based defenses against theater ballistic missiles and land-attack cruise missiles. The Army has made credible and evolutionary progress in enhancing theater IAMD capabilities, including the Integrated Air and Missile Defense Battle Command System (IBCS). IBCS will integrate its air and missile defense sensors, launchers, and command and control networks. IBCS achieved initial operating capability from the Army on May 1, 2023, and the system is ready for operational fielding. It will be part of the Guam Defense System. However, one

critical area that has yet to see progress is land-based cruise missile defense (CMD). The Army's current plans for IFPC 2-I have not progressed as quickly as intended and will delay the fielding of any significant Army cruise missile defense capability until the late 2020s.[4] This critical problem significantly impacts the timeline and potential effectiveness of the Guam Defense System. Meanwhile, the USMC is pursuing a mobile variant of the Iron Dome system since the lack of defense against cruise missiles and other aerial threats has been a critical capability gap. The USMC is expecting three batteries of its Ground Based Air Defense (GBAD) Medium Range Intercept Capability (MRIC) systems in the FY25 to FY27 timeframe and starting to field as early as FY26.

The Air Force is "the only military service that lacks clear authority to develop and procure surface-based air and missile defense (AMD) systems to protect its own forces."[5] The Air Force has relied on Army air and missile defense (AMD) capabilities for active defense of air bases since decisions in the 1950s led to the Army owning both point and area defense. Over the years, the Air Force and Army sparred over these roles and functions with no clear resolution by DoD. However, Congress took notice of the need to help resolve the ambiguity and responded with Section 156 of the FY2021 NDAA. That legislative language required the Air Force and Army to "jointly develop and carry out a strategy to address the defense of air bases and Pre-positioned Sites outside the continental United States…"[6] Although this report was due to Congress on June 1, 2021, as of mid-September 2023, there appears to be no public record of this final report except for a recent public discussion on August 29, 2023. Given the magnitude of the threats, the Air Force will likely need to assume greater responsibilities for defending some of its theater expeditionary air bases even if the Army increases its capability, capacity, forward posture, and presence in the Indo-Pacific. However, it is unlikely that the Army will be able to support active defenses at expeditionary bases significantly. Still, it should do much more at Main Operating Bases (MoBs) and other sites.
The Space Force is becoming increasingly important as space superiority is critical for the nation and IAMD—so much so that some believe ISAMD (Integrated Space, Air, and Missile Defense) should emerge. As part of space superiority, the most important role and mission for the USSF is its missile strategic warning and tracking missions. The Space Force's rise likely gave POTUS impetus to sign a new Unified Command Plan (UCP) that moved global missile defense operational support responsibilities from STRATCOM to SPACECOM on April 25, 2023.

The Joint IAMD Organization (JIAMDO) plays a critical role in the Department that is unique and important for the future of theater IAMD. JIAMDO has an across-the-board role of coordinating the nation's missile defense programs. The JCO was established in January

4 Janes IHS Markit, "Bridging The Gap: U.S. Tactical Short-Range Air-Defence Programmes," June 29, 2021.

5 Alan J. Vick, Sean M. Zeigler, Julia Brackup, and John Speed Meyers, *Air Base Defense: Rethinking Army and Air Force Roles and Functions* (Santa Monica, CA: RAND, 2020), p. 1, https://www.rand.org/pubs/research_reports/RR4368.html.

6 *William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021*, 116th Congress, H.R. 6395, Public Law 116-283, January 1, 2021, Section 156, p. 61.

2020. DOD made the USA the executive agent for sUAS (Class 1-3) threats. The establishment of JCO has de facto acknowledged an ongoing UAS/C-UAS arms race where standard processes will not suffice.

Toward Comprehensive IAMD

Current IAMD plans rely on existing defensive interceptors that cost too much, deliver too little, and do not sufficiently address the growing threat of massed (or salvo) air and cruise missile attacks. Alternative approaches should include layered, comprehensive, and distributed IAMD concepts that address the full spectrum of threats. Specifically, the new concepts developed should be built around concentric rings (or layers): an outer ring that can detect and engage hostile targets far beyond the range of ground-based defensive systems located at or near a threatened base; an inner ring that can protect the area immediately surrounding that base; and a close-in ring that provides point defense against specific targets on that base. These same concepts can be represented with future Guam Defense System applications.

The defense of Guam remains critical due to its strategic importance as the hub for concentrating long-range strike efforts along the second island chain in the Indo-Pacific region. Guam is already vulnerable to complex attacks of large salvos of ballistic and cruise missiles and UAS. Efforts to develop layered, comprehensive, and distributed integrated air and missile defenses are crucial to U.S. military operations in the Indo-Pacific.

However, based on the details released and the goals of the program, several critical issues need prompt attention:

- The first is the timeline for improvements to Guam's defenses. As one expert has noted, the Department of Defense appears to have "settled on the most expensive, least efficient and slowest delivered possible plan."[7]
- The second is the impact of delays in developing key IAMD capabilities. Critical systems are still in doubt, especially regarding cruise missile defense. The current plan is likely very dependent on the Army's IFPC 2-I close-in cruise missile defense.
- The third is the need for more attention to personnel and infrastructure requirements.[8] Indeed, the non-material (i.e., DOTMILPF) implications of Guam's future defense may be the Achilles heel of current plans because significant personnel will be needed to operate these systems. These personnel will impact both costs and timelines.[9]

7 RADM (ret) Mark Montgomery, Transcript-MDAA Virtual Event: "The Missile Defense 'Must Do' List for the FY-24 NDAA," May 17, 2023, p. 14.

8 RADM (ret) Mark Montgomery, Transcript-MDAA Virtual Event: "Missile Defense of Guam: No Time To Waste—No Time To Lose," August 17, 2023, pp. 14-15.

9 Ibid.

More cost-effective solutions need exploration that can be implemented ASAP. There is a need for innovation and out-of-box thinking. For instance, the Department should consider using Guam Army National Guard (ARNG) and USMC personnel by converting some existing personnel or units to air defense artillery units. With IFPC 2-I delayed, USMC GBAD MRIC (for cruise missile defense) could help shrink timelines and contain costs—especially if some USMC personnel currently associated with DPRI and Camp Blaz are converted to defend Guam. In addition, the planned movement of a detachment of the Republic of Singapore Air Force (RSAF) fighters to AAFB (by 2029) should be evaluated (or reevaluated) in light of the Guam Defense System and the new importance for USAF forces at AAFB.

Conclusion and Recommendations

DoD and Congress should support the development of operating concepts and a new generation of cost-effective active and passive defenses and attack operations capabilities that could help protect the U.S. military's forward bases, ports, and pre-positioned sites against salvo attacks and complex salvo attacks.

The Department of Defense and others should consider the following recommendations (the full list of recommendations with complete rationale is at the end of Chapter 4):

Continue fully supporting USINDOPACOM's #1 PDI goal—the Guam Defense System. DoD, USINDOPACOM, and Congress should continue to support the Guam Defense System. However, the DoD and Congress must demand urgency for a timely implementable plan with needed capability, cost-effectiveness, minimal personnel, and infrastructure.

Field UAS with sensors to perform persistent detection/early warning of salvo attacks. Sensors (active electronically scanned arrays, infrared, and others) could be integrated into current generation and future UASs (including HALE UAS) to help detect and provide early warning of missile salvos and associated "track" information.

Acquire multiple types of HPM/EW defenses. DoD should take advantage of nascent HPM technologies demonstrated by the THOR C-UAS program and its follow-on programs (e.g., Mjolnir). In addition, the DoD should procure higher power and longer-range HPM/EW systems capable of fighting UAS swarms, cruise missiles, and other threats.

Develop Alternatives for IFPC 2-I for INDOPACOM—Cost-Effective & Timely Cruise Missile Defense (CMD). Other options should be considered to fill capability gaps due to delays in IFPC 2-I, including the USMC's GBAD MRIC, gun systems (e.g., HGWS), and other options.

Responsibilities for IAMD defense inside and outside DoD must improve for effectiveness. DoD, working with Congress and others, must continue to work out the seams associated with the labyrinth of organizations that are often less than optimum in the rapidly changing IAMD world.

Enhanced IAMD Integrated Test Bed for USINDOPACOM. Best practices for development, innovation, testing, and training include the use of an ITB that is separate from the operational system, but that is sufficiently robust and sophisticated that it can emulate the operational architecture, conditions, and threats and, by doing so, provide for realistic training (including TTPs), experimentation, and IAMD development.

CHAPTER 1

Understanding the Challenge

Introduction

One of the most critical operational challenges the United States is likely to confront in a future conflict, particularly in the Indo-Pacific theater, is the threat of massed precision-guided air and missile attacks on overseas ports, bases, and other key facilities. Since 1985, the Department of Defense has invested hundreds of billions of dollars to defend against ballistic missile attacks on the United States, as well as its forward bases and forward-operating forces.[10] Despite these investments, the United States still lacks the ability to defeat large numbers of ballistic missiles, cruise missiles, and unmanned aerial systems (UAS).

Meanwhile, the proliferation of precision-guided weapons (PGWs) and delivery systems has continued. Consequently, the cost of traditional kinetic defenses against precision air and missile attacks vastly exceeds the cost of offensive weapons and their supporting command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems. Relatedly, some potential adversaries can now employ large salvoes of PGWs.[11] This is especially problematic because, during a crisis or conflict, many U.S. integrated air and missile defense (IAMD) capabilities would need to be mobilized and moved into theater, usually from the continental United States. These movements would be a necessary

10 Center for Strategic and International Studies, "MDA and the Color of Money: Graphs," https://www.csis.org/programs/mda-and-color-money-graphs; From 1985 through 2021, the SDIO, BMDO and MDA had approximately $270B (CY2017$) in budget authority (BA) for their programs.

11 Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defense* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016), p.1, https://csbaonline.org/research/publications/winning-the-salvo-competition-rebalancing-americas-air-and-missile-defenses#:~:text=Senior%20Fellows%20Mark%20Gunzinger%20and,future%20ability%20to%20project%20power.

precursor to introducing follow-on forces, materiel, and supplies.[12] Although this concept of employment made sense when threats were less severe, that is no longer the case.[13]

The purpose of this report is to examine the requirements for layered, comprehensive, and distributed IAMD capabilities, given the combination of rising threats to U.S. forces and the declining relevance of existing operational concepts for defense against those threats. In particular, this report focuses principally on the "active defense" component of IAMD.

In general, IAMD is defined as "the integration of capabilities and overlapping operations" for the purpose of "negating an enemy's ability to create adverse effects from air and missile capabilities," and includes three main elements: Offensive Counterair (OCA) attack operations, active air and missile defense, and passive air and missile defense (hereafter attack operations, active defenses, and passive defenses, respectively).[14] At one end of the spectrum, attack operations aim to prevent initial or follow-on enemy strikes by degrading the forces that conduct or support them, including aircraft, bases, and missile launchers.[15] At the other end, passive defenses are intended to avoid, mitigate, or minimize the effects of enemy attacks and ensure functionality by substitution and redundancy. In addition, after an enemy attack, passive defenses enable the reconstitution or recovery of friendly forces. In between attack operations and passive defenses, active defenses are designed to defeat an adversary's aircraft or missiles after strikes are launched.[16]

Although the precise mix of all three elements will vary depending on the circumstances,[17] the different components of IAMD highlight the need for a layered, comprehensive, and distributed defense. A layered defense comprises multiple and ideally overlapping "rings," in which a combination of kinetic and non-kinetic capabilities can increase the effectiveness of active defense by engaging different types of threats at different ranges. A comprehensive defense involves positioning the right IAMD assets in the right locations, in sufficient quantities,

12 Consequently, IAMD assets are generally among the first and highest priority assets to be deployed in the event of crisis or conflict. It is even more problematic when major IAMD force structure is in the Reserve Component (RC) due to mobilization timelines that do not allow for rapid deployment. Currently, most of the proposed U.S. Army cruise missile defense (CMD) force structure is in the Army National Guard (ARNG).

13 See Carl Rehberg and Josh Chang. *Moving Pieces: Near-Term Changes to Pacific Air Posture*. Washington, DC: Center for Strategic and Budgetary Assessments (CSBA), 2022, https://csbaonline.org/research/publications/moving-pieces-near-term-changes-to-pacific-air-posture.

14 Joint Chiefs of Staff, "Joint Publication 3-01: Countering Air and Missile Threats," April 21, 2017, pp. I-10, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf. Some CSBA publications "counterstrike" use for OCA attack operations. "OCA [attack] operations destroy or neutralize enemy aircraft, missiles, launch platforms, and their supporting structures and systems both before and after launch, as close to their source as possible." Ibid., pp. I-5.

15 See Joint Chiefs of Staff, "Joint Publication 3-01: Countering Air and Missile Threats," April 21, 2017, Chapter IV, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf. It should be noted that counterstrike is a term used by allies like Japan.

16 Koichi Arie and Naohiko Yamaguchi, "U.S. Initiative for Integrated Air and Missile Defense (IAMD)," *NIDS Security Studies*, vol. 20:1, December 2017, http://www.nids.mod.go.jp/english/publication/kiyo/pdf/2018/bulletin_e2018_3.pdf.

17 Christopher Lynch, Rachel Costello, Jacob Heim, et al. "Operational Imperative: Investing Wisely to Bolster U.S. Air Bases Against Chinese and Russian Attacks," 2023, https://www.rand.org/pubs/perspectives/PEA1996-1.html

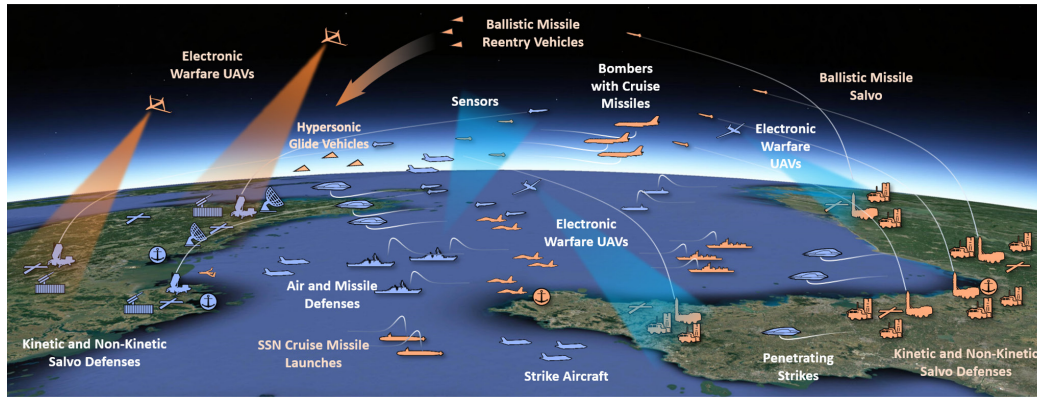
and with the proper passive defenses (from hardened shelters to concealment measures) to enhance their survivability.[18] A distributed defense builds on the longstanding virtues of dispersal to reduce the vulnerability of any IAMD architecture, as well as emerging concepts such as "any sensor, best shooter" to maximize the effectiveness of its varied components.

This report addresses how DoD could take advantage of mature and maturing technologies—including medium-range high-energy lasers (HELs), high-power microwave or electronic warfare (HPM/EW) systems, guided projectiles launched by rapid-firing guns, and low-cost surface-to-air missiles (SAMs)—to develop higher capacity and more cost-effective air and missile defenses for its overseas bases. It focuses, in particular, on defenses against large salvos of cruise missiles and high density UAS attacks, which tend to receive far less attention than small numbers of ballistic missile strikes but present unique challenges given that they represent a lower cost, higher volume option for an attacker.

Salvo Competitions

In line with previous CSBA monographs, this report uses a "salvo competition" framework to assess promising concepts and capabilities to defend U.S. bases against guided weapon attacks.[19] The term "salvo competition" refers to the dynamic between opposing militaries that seek to strike and defend with precision against large numbers of air-, ground-, and sea-launched weapons (see Figure 1). In this competition, each combatant seeks to gain an advantage by continuously increasing the size and survivability of its offensive strikes and the lethality and capacity of its defenses against attacks.

FIGURE 1: ILLUSTRATIVE SALVO COMPETITION CAPABILITIES



Source: Graphic created by CSBA.

18 Ibid.

19 For other CSBA reports that address these capabilities, see Mark Gunzinger and Bryan Clark, *Sustaining America's Precision Strike Advantage* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015); and Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses* (Washington, DC: Center for Strategic and Budgetary Asessments, 2016).

It is only in the last decade that potential U.S. adversaries attained the capability to launch large salvos of guided weapons against U.S. forces and bases. As a result, the Department of Defense has long allocated most of its missile defense resources toward defeating a small number of nuclear-armed ballistic weapons that could be launched by North Korea or other rogue states. For example, the 2010 Ballistic Missile Defense Review (BMDR) concluded that the United States should continue to focus on protecting the U.S. homeland against limited ballistic missile attacks and defeating ballistic missile threats to its forces while also emphasizing the importance of regional missile defense cooperation.[20] The 2019 Missile Defense Review (MDR) continued this focus on homeland missile defense against attacks by rogue states; it also addressed the need for robust regional cruise and ballistic missile defense against great power adversaries, including offensive capabilities to degrade an adversary's ability to launch missiles.[21] The 2022 MDR put aside the emphasis on rogue state ballistic missiles in favor of a focus on strategic competition with China and Russia.[22]

The traditional bias toward defeating ballistic weapons—and, in particular, small numbers of nuclear-armed ballistic weapons—has finally changed to reflect the evolved threat.[23] Improving defenses against salvos that include not only ballistic missiles, but also subsonic cruise missiles, supersonic cruise missiles, hypersonic weapons, and UAS armed with warheads is now a key imperative.[24] Over the last two decades, China and Russia have invested heavily in advanced military systems to offset the superior conventional capabilities of the United States and its allies. Their so-called anti-access and area-denial (A2/AD) complexes of integrated air defense systems (IADS), long-range precision strike platforms, and other advanced weaponry are designed to raise the cost to the United States and other countries attempting to project military power into their respective regions.[25] Many of China's and Russia's long-range strike systems were designed specifically to attack theater

20 Department of Defense, Ballistic Missile Defense Review Report (Washington, DC: DoD, February 2010), p. iii, https://dod.defense.gov/Portals/1/features/defenseReviews/BMDR/BMDR_as_of_26JAN10_0630_for_web.pdf.

21 Department of Defense, *2019 Missile Defense Review* (Washington DC: 2019), https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF. See also Henry Obering III and Rebeccah L. Heinrichs, "Missile Defense for Great Power Competition: Outmaneuvering the China Threat," *Strategic Studies Quarterly* (Winter 2019), https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-13_Issue-4/Heinrichs.pdf. The 2010 Ballistic Missile Defense Review had a strong focus on regional missile defense, but it did not include the need for offensive strikes (or counterstrike) as part of that regional defense.

22 Department of Defense, *2022 Missile Defense Review* (Washington DC: 2022), https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF. It should be noted that this 2022 MDR policy shift has not fully penetrated Service or MDA acquisition strategies as of this publication.

23 Ibid.

24 Paul Sonne, "Pentagon looks to adjust missile defense policy to include threats from Russia, China," *Washington Post*, March 2, 2018, https://www.washingtonpost.com/world/national-security/pentagon-looks-to-adjust-missile-defense-policy-to-include-threats-from-russia-china/2018/03/01/2358ae22-1be5-11e8-8a2c-1a6665f59e95_story.html.

25 "An enemy IADS attempts to destroy, disrupt, or neutralize intelligence collection and air and missile attacks or other penetrations of their airspace." Joint Chiefs of Staff, "Joint Publication 3-01: Countering Air and Missile Threats," April 21, 2017, p. xviii, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_01.pdf.

airbases, ports, and other facilities that are critical to U.S. military operations.[26] These weapon systems undermine security assurances made by the United States to its allies and partners and could offer incentives for a great power aggressor to strike first in a crisis with a surprise attack or *fait accompli*.[27]

The Salvo Threat from China

According to the National Air and Space Intelligence Center (NASIC), "China continues to have the most active and diverse ballistic missile development program in the world."[28] Specifically, it has developed a sophisticated mix of more than 1,250 surface-launched, sub-launched, and air-launched ballistic and cruise missiles that are capable of striking military and civilian targets across Taiwan, the Japanese Islands, and beyond.[29] China's conventional missile inventory currently comprises four Short-Range Ballistic Missile (SRBM) types, one Medium-Range Ballistic Missile (MRBM) type, two Intermediate-Range Ballistic Missile (IRBM) types, as well as three different Land Attack Cruise Missile (LACM) types and at least one Hypersonic Glide Vehicle (HGV).[30]

China's principal platform for employing long-range air-launched missiles is the H-6 bomber aircraft, which is based on the former Soviet Tu-16 medium bomber. The aircraft design has undergone several modifications over the years and is capable of conducting long-range strike missions with both bombs and long-range air-to-surface missiles (including cruise

26 Mark Gunzinger, Bryan Clark, David Johnson, and Jesse Sloman, *Force Planning for the Era of Great Power Competition* (Washington, DC: CSBA, 2017), p. 32-35, 70-80. Also see David A. Shlapak and Michael Johnson, "Reinforcing Deterrence on NATO's Eastern Flank: Wargaming the Defense of the Baltics," (Santa Monica, CA: RAND, 2016).

27 Elbridge Colby, *The Strategy of Denial: American Defense In An Age of Great Power Conflict* (Yale University Press, 2021).

28 Defense Intelligence Ballistic Missile Analysis Committee (DIBMAC), "Ballistic and Cruise Missile Threat," July 2020, https://media.defense.gov/2021/Jan/11/2002563190/-1/-1/1/2020%20BALLISTIC%20AND%20CRUISE%20MISSILE%20THREAT_FINAL_2OCT_REDUCEDFILE.PDF. See Jane's IHS Markit, "China—Strategic Weapon Systems," April 22, 2021, Janes: China - Strategic Weapon Systems. For details on China Missile Defense industrial base, see Peter Wood and Alex Stone, *China's Ballistic Missile Industry* (Montgomery, AL: China Aerospace Studies Institute, 2021), https://www.airuniversity.af.edu/CASI/Display/Article/2599627/chinas-ballistic-missile-industry/.

29 Japan Ministry of Defense, *Defense of Japan 2019*, https://www.mod.go.jp/en/publ/w_paper/wp_2019.html; Department of Defense, *Military and Security Developments Involving the People's Republic of China* (Washington, DC: DOD, November 2021), https://www.defense.gov/News/Releases/Release/Article/2831819/dod-releases-2021-report-on-military-and-security-developments-involving-the-pe/.

30 Missile Defense Project, "Missiles of China," Missile Threat, Center for Strategic and International Studies, June 14, 2018, last modified April 12, 2021, https://missilethreat.csis.org/country/china/. SRBMs have ranges between 300 and 1,000 km; MRBMs have ranges between 1,000 and 3,000 km; IRBMs have ranges between 3,000 and 5,000 km; and ICMBS have ranges over 5,500 km. For more information on ballistic missile classifications, see Defense Intelligence Ballistic Missile Analysis Committee, *2020 Ballistic and Cruise Missile Threat* (Wright-Patterson AFB, OH: National Air and Space Intelligence Center, 2020), p. 8, https://www.nasic.af.mil/News/Article-Display/Article/2468163/nasic-dibmac-release-unclassified-missile-assessment/.

missiles and an air-launched ballistic missile (ALBM)).[31] In addition to the venerable H-6 bombers and all their variants, China is also developing a new long-range stealth bomber—its first dedicated strategic bomber—designated the Xian H-20. The H-20 is anticipated to have an unrefueled range of 8,500 km (4,600 nm), a munitions payload of over 20,000 lbs. and to be nuclear-capable.[32] This aircraft will bolster the third leg of a People's Liberation Army (PLA) nuclear triad while delivering significant conventional power projection capabilities against the 2nd Island Chain and beyond.

Although rarely highlighted, the PLA Air Force (PLAAF) has aggressively modernized its fighters over the last decade while fielding new air-to-air missiles (AAMs), air-to-ground munitions (AGMs), and new concepts of operation (CONOPS). One advanced air-to-air missile is the short-range PL-10, which has an imaging infrared seeker and thrust-vector control capability. However, the PLAAF is fielding beyond-visual-range air-to-air missiles (BVR AAM) such as the PL-15 and PL-21 that feature ramjet engines and active electronically scanned array (AESA) radar seekers.[33] The combination of airborne early warning and command and control (AWACS) aircraft with advanced sensors that can cue low observable J-20s carrying BVR AAMs will improve the PLAAF's ability to engage high-value aircraft assets (HVAAs) such as Air Force aerial refueling tankers, battle management, and intelligence platforms over long ranges.[34]

The UAS threats from China will be across the board in all UAS group sizes. The larger UAS group sizes (4 & 5) are becoming less distinguishable from traditional manned aircraft in terms of their capabilities. Nevertheless, these UAS threats present a salvo threat for the United States and Japan due to limited inventories of AAMs, interceptor aircraft, and SAMs to defeat them kinetically. The small UAS (sUAS) threat (which includes low-cost attritable UAS) and sUAS swarms may be the most problematic, as there are currently few dedicated sensors for detection, a paucity of Battle Management Command and Control (BMC2) assets, and limited counters for these threats (both kinetic and non-kinetic). There is also evidence

31 Office of the Secretary of Defense (OSD), *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (Washington, DC: Department of Defense, 2022), https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF.

32 Ibid.

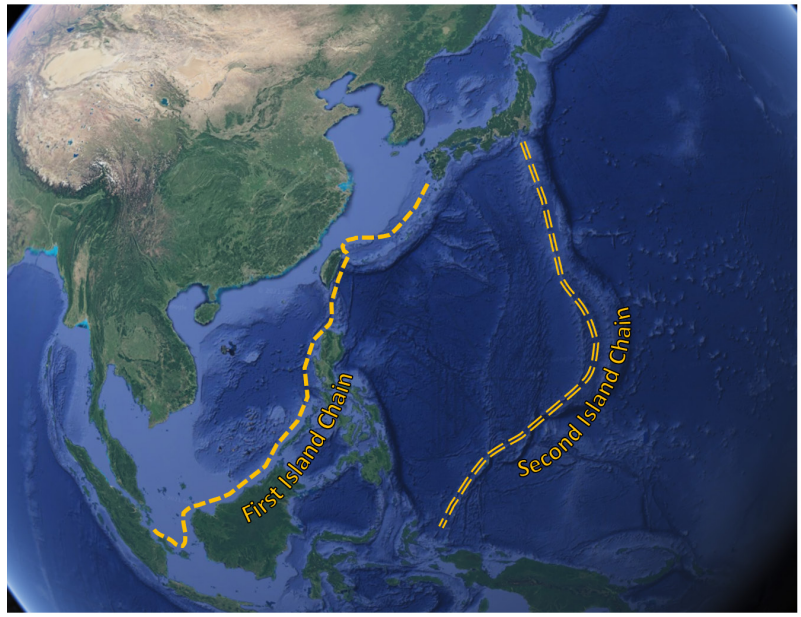
33 John Stillion, *Trends in Air-to-Air Combat: Implications for Future Air Superiority* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015); and Jeffrey Lin and P.W. Singer, "This New Ramjet Engine Could Triple The Range of Chinese Missiles," *Popular Science,* June 12, 2017, https://www.popsci.com/chinas-new-ramjet-engine-triple-range-missiles/. AESA is a type of phased array antenna consisting of a matrix of small, solid state transmit/receive modules each capable of generating its own signal, allowing AESA radars to produce multiple, simultaneous radar beams at different frequencies to perform multiple functions simultaneously.

34 Mark Gunzinger, Carl Rehberg, and Lukas Autenried, *Five Priorities for the Air Forces Future Combat Air Force*, (Washington, DC: Center for Strategic and Budgetary Assessments, 2020), https://csbaonline.org/research/publications/five-priorities-for-the-air-forces-future-combat-air-force. This scenario is evolving such that could include a PLAAF high/low mix of 5th GEN fighters with J-8 type drones and likely PLA versions of our collaborative combat aircraft (CCA) that impacts AAM and HVAA security.

that Chinese engineers are contemplating, and may be developing, hypersonic swarming unmanned combat aerial vehicles (UCAVs).[35]

Ultimately, with this set of existing and emerging capabilities, China could conduct a wide spectrum of attacks in the western Pacific, ranging from limited conventional attacks involving ballistic or cruise missiles to full-scale attacks comprising the full range of land-launched, sea-launched, and air-launched ballistic and cruise missiles and UAS fired from multiple axes of attack around the perimeter of Japanese air space and sovereign territory.

FIGURE 2: FIRST AND SECOND ISLAND CHAINS[36]



Source: Graphic created by CSBA.

The First Island Chain

Both U.S. planners and the PLA have delineated the Indo-Pacific into island chains.[37] The First Island Chain encompasses the East and South China Seas, extending from Japan and Taiwan to the Philippines and the Indonesian Archipelago.

35 Shixun Luo et al., "Network for Hypersonic UCAV Swarms," *Science China Information Services* 63, no. 140311, March 10, 2020, https://link.springer.com/article/10.1007%2Fs11432-019-2765-7.

36 The First Island Chain includes the Japanese island of Kyushu, down the Ryukyus to the north of Taiwan, west towards Luzon, along Palawan and to Singapore. The Second Island Chain includes the northern Marianas, the Volcano Islands, down to Guam, stretching south to Palau and New Guinea. The diagram reflects a threat perspective regarding the island chains found in Office of the Secretary of Defense, *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (Washington, DC: Department of Defense, 2021), p. 62.

37 Andrew S. Erickson and Joel Wuthnow, "Why Islands Still Matter in Asia," *National Interest*, February 5, 2016, https://nationalinterest.org/feature/why-islands-still-matter-asia-15121.

China continues to assert its territorial claims on the South China Sea and cites the strategic importance of the South China Sea to its political, economic, and military interests. To that end, China has created and occupied artificial features in the South China Sea, including building air and naval installations and stationing offensive and defensive missiles on them. Moreover, China has been expanding its sea control capabilities in the South China Sea. For example, in February 2021, six Chinese H-6K bombers escorted by four J-16 fighters reportedly conducted a simulated attack on a U.S. aircraft carrier and penetrated Taiwanese airspace in the process.[38] In June 2021, a large formation of Chinese bombers, fighters, early warning, electronic warfare, and anti-submarine warfare aircraft penetrated Taiwanese airspace, flying through the Air Defense Identification Zone (ADIZ) on the eastern side of the island.[39] Such activity is ongoing and will likely continue.

In addition to China's expanded activities in the South China Sea, Beijing has also steadfastly built the capacity to influence air and sea control over First Island Chain nations. China has done this primarily by developing and deploying air-, land- and sea-based ballistic and cruise missiles. China's existing mobile offensive missiles have the range and the numbers to conduct ballistic and cruise missile attacks against all or part of the sovereign territories of the First Island Chain nations. China's DF-17 MRBM, which employs a hypersonic glide vehicle (HGV), has a range of 1,800 to 2,500 km.[40] China also has DH-10/CJ-10/20 subsonic cruise missiles for surface and air launch, supersonic cruise missiles, as well as a variety of UAS and sUAS that could be employed by multiple systems and in swarms.[41] China's large inventory of ground-launched weapons means they can fire most of these simultaneously and with mass fires versus PLAAF and PLA Navy (PLAN) platforms that deliver a limited payload and have to return to rearm. The PLA Rocket Force's (PLARF's) ability to launch a massed attack with little warning (especially in the First Island Chain) is a significant advantage of their current (and projected) force structure and posture that the United States and its allies and partners have not mitigated.[42]

38 Kathrin Hille and Demetri Sevastopulo, "Beijing Lays Down a Marker in South China Sea," *Financial Times*, February 2, 2021, https://www.ft.com/content/858e24a9-1370-4b1e-853f-845eaf7d25c6.

39 Liu Xuanzun, "Record PLA Exercise 'Warns Taiwan Secessionists, US Carrier Activity'", *Global Times*, June 16, 2021, https://www.globaltimes.cn/page/202106/1226323.shtml.

40 Missile Defense Project, "DF-17," Center for Strategic and International Studies, last updated August 2, 2021, https://missilethreat.csis.org/missile/df-17/. Currently, there is no known capability to intercept HGVs but there are promising programs to include a modified SM-6 and a new interceptor as part of the Regional Glide Phase Weapon program. Jason Sherman, "Aegis, AMDR detected, tracked and launched simulated SM-6 against long=range hypersonic glide vehicle," *Inside Defense,* January 21, 2021, https://insidedefense.com/daily-news/aegis-amdr-detected-tracked-and-launched-simulated-sm-6-against-long-range-hypersonic.

41 Office of the Secretary of Defense (OSD), *Annual Report to Congress: Military and Security Developments Involving the People's Republic of China* (Washington, DC: Department of Defense, 2022), pp. 59-61, https://media.defense.gov/2022/Nov/29/2003122279/-1/-1/1/2022-MILITARY-AND-SECURITY-DEVELOPMENTS-INVOLVING-THE-PEOPLES-REPUBLIC-OF-CHINA.PDF

42 For numerous publications on PLA aerospace capabilities and force structure, see the China Aerospace Studies Institute (CASI), https://www.airuniversity.af.edu/CASI/

At present, the air and missile defense systems fielded by the U.S. and First Island Chain nations are inadequate for the task of defending against salvo attacks involving large numbers of offensive weapons, sophisticated threats using advanced systems such as HGVs, and complex attacks that unfold across multiple axes. The national air and missile defense systems do not, in most cases, provide defense in depth, nor are they comprehensive or distributed.[43]

The Second Island Chain

The Second Island Chain is anchored by the U.S. territory of Guam, which lies approximately 3,000 km east of China. Guam is home to Naval Base Guam on the island's southwest side and Andersen Air Force Base (AAFB) on the island's north end. Because of Guam's strategic importance, it could be a lucrative target for air and missile attacks in the event of hostilities between the United States and China.

A future Chinese attack on Guam could include cruise missiles, ballistic missiles, and hypervelocity glide vehicles launched on widely varying trajectories from different azimuths around Guam. Potential weapon systems for such an attack might include:

- PLAAF H-6 strategic bombers carrying cruise missiles, hypersonic missiles, or air launched ALBMs.[44]
- The DF-26 road-mobile, dual-capable IRBM.[45]
- The DF-27—a new IRBM or ICBM, which is currently in development.[46]
- Hypersonic Glide Vehicles (HGVs) on one or more missile systems.[47]

43 The MDR advocates IAMD a posture that is "comprehensive, layered, mobile." For purposes of this paper, IAMD assets need to be distributed with passive defenses (e.g., shelters) if they cannot be mobile. However, they should have some of both (be mobile and distributive—IAMD TELs distributed and in protective shelters). Department of Defense, *2022 Missile Defense Review*. Washington, DC: DoD, 2022, p. 12, https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

44 Thomas Newdick, "China's H-6K Bomber Spotted with New Air-Launched Ballistic Missile", *The War Zone*, November 3, 2022, https://www.thedrive.com/the-war-zone/chinas-h-6k-bomber-spotted-with-new-air-launched-ballistic-missile.

45 Jane's IHS Markit, "DF-26", March 13, 2023, https://customer.janes.com/display/JSWSA399-JSWS. This missile was initial labeled the "Guam" missile but the DF-26 can go after numerous other targets beside Guam.

46 OSD, *Annual Report to Congress*, 2022, p. 65.

47 Tanmay Kadam, "Countering China's Greatest & Longest Hypersonic Missile—US Says Its Missile Killer Program Just Not Ready," *The Eurasian Times*, May 28, 2022, https://eurasiantimes.com/us-says-its-missile-killer-program-just-not-be-ready-hypersonic/.

- *Shang*-class Type 93 attack submarines carrying land-attack cruise missiles.[48]
- Multiple types of UAS—likely from a variety of domains and platforms.[49]

Any strike using such systems would produce complex salvo attacks with multiple missile profiles, from multiple axes, and with high degrees of simultaneity.

FIGURE 3: PLAAF H-6K MEDIUM BOMBER WITH CRUISE MISSILES

A Growing Premium on Effective IAMD

In sum, the U.S. military faces significant threats to its basing infrastructure in the western Pacific. Given the vast expanse of the theater, U.S. forces must transport almost everything they need that is not already in theater or pre-positioned forward across thousands of miles of ocean. Consequently, those forces are heavily dependent on logistics and sustainment sites highly concentrated around a few key nodes, such as Guam, Okinawa, and the main islands of Japan, all of which are within range of PLA precision weapons systems. Consequently, effective IAMD is a requirement for successfully being able to withstand large initial attacks on U.S. and allied forces and territory, recover the initiative, and subsequently establish the conditions needed to achieve an acceptable end to hostilities. The next chapter will discuss the state of current efforts to defend against emerging threats, especially the threat posed by salvos of ballistic missiles coupled with non-ballistic threats such as cruise missiles, hypersonic missiles, and emerging UAS.

48 H.I. Sutton, "The Chinese Navy's Most Powerful Attack Submarine: The Type-093A," *Naval News*, November 15, 2020, https://www.navalnews.com/naval-news/2020/11/the-chinese-navys-most-powerful-attack-submarine-the-type-093a/. Missile Defense Project, "YJ-18," *Missile Threat*, Center for Strategic and International Studies, June 25, 2020, last modified July 28, 2021, https://missilethreat.csis.org/missile/yj-18/.

49 Tyler Rogoway and Joseph Trevilvick, "Mysterious Drone Incursions Have Occurred Over U.S. THAAD Anti-Ballistic Missile Battery In Guam," *The War Zone*, November 27, 2020, https://www.thedrive.com/the-war-zone/36085/troubling-drone-incursions-have-occurred-over-guams-thaad-anti-ballistic-missile-battery.

CHAPTER 2

Current Theater Active Air and Missile Defenses

Over the last decade, DoD has acknowledged the need to improve the resiliency of its overseas basing posture to include active and passive defenses.[50] The 2022 National Defense Strategy (NDS) highlights three major strategy logics for deterrence: 1) denial, 2) resilience, and 3) cost imposition.[51] The 2022 NDS is consistent with the 2018 National Defense Strategy that emphasizes transitioning the U.S. military's overseas posture "from large, centralized, unhardened infrastructure to smaller, dispersed, resilient, adaptive basing that include active and passive defenses."[52] Notably, the *2022 Missile Defense Review* (MDR) stated: "IAMD represents an effort to move beyond platform-specific missile defense toward a broader approach melding all missile defeat capabilities – defensive, passive, offensive [OCA attack operations], kinetic, non-kinetic – into a comprehensive joint and combined construct."[53]

The Services are developing concepts to increase the resiliency of their bases, ports, facilities, and forces operating in areas that could be subject to salvo attacks. For instance, the

50 DoD organizations have used different terms to describe the resiliency of its overseas posture, including "operational resiliency," "joint resiliency," and "posture resiliency." Operational resiliency is an overarching or umbrella term. The *2018 National Defense Strategy* (NDS) describes posture resilience as "forces that can deploy, survive, operate, maneuver and regenerate in all domains while under attack." Department of Defense, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military's Competitive Edge* (Washington DC: DoD, January 2018), p. 6, https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf. Also see Alan J. Vick, Air *Base Attacks and Defensive Counters: Historical Lessons and Future Challenges* (Santa Monica, CA: RAND Corporation, 2015).

51 Department of Defense, *2022 National Defense Strategy*. Washington, DC: DoD, 2022, p. 8. https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF

52 Department of Defense, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military's Competitive Edge*, p. 6.

53 DoD, *2022 Missile Defense Review*. 2022, p. 8.

Air Force is continuing to develop a concept of operations it calls Agile Combat Employment (ACE) to help increase the resiliency of its air bases.[54] The Marine Corps is testing concepts for conducting distributed operations that take advantage of its ability to operate from expeditionary bases using its Expeditionary Advanced Base Operations (EABO) concept.[55] Given the growing threat of salvo attacks, these concepts should include affordable, high-capacity, active air and missile defenses that can be deployed rapidly to support distributed operations.

Much of this effort reflects changing priorities as DoD shifts from two decades of counterinsurgency to a focus on great power competition. In the aftermath of 9/11, the United States adapted to counter-insurgency warfare by funding new programs and winding down others. The Army, for example, found itself having to "deprioritize air defense units' personnel, training and equipment, allowing air defense priorities to atrophy."[56] The Air Force, for its part, has been slow to acquire the capabilities needed to conduct sustained combat operations in contested and highly contested environments.

Missile Defense Agency

The Missile Defense Agency (MDA) is responsible for developing a layered Ballistic Missile Defense System for DoD that includes capabilities to intercept ballistic missiles in their boost, midcourse, and terminal phases of flight (see Figure 4).[57] Although MDA has had a mixed record when it comes to testing and fielding new ballistic missile defenses, its programs have had several recent successes, including the first intercept of an ICBM target by its Ground-based Midcourse Defense (GMD) system and an Aegis SM-3 Block IIA intercept of a medium-range ballistic missile target.[58] Although MDA has not been responsible

54 This general concept was used in Europe toward the end of the Cold War. See Christopher J. Bowie, "The Lessons of Salty Demo," *Air Force Magazine*, March 1, 2009, https://www.airforcemag.com/article/0309salty/. For more information on these constructs, see United States Air Force, Air Force Doctrine Note 1-21. Agile Combat Employment, 1 December 2021, https://www.doctrine.af.mil/Portals/61/documents/AFDN_1-21/AFDN%20 1-21%20ACE.pdf. For an assessment of ACE, see Christopher Lynch, Rachel Costello, Jacob Heim, et al. "Operational Imperative: Investing Wisely to Bolster U.S. Air Bases Against Chinese and Russian Attacks," 2023, https://www.rand.org/pubs/perspectives/PEA1996-1.html.

55 United States Marine Corps, Expeditionary Advanced Base Operations (EABO) Handbook (Version 1.1), June 1, 2018, https://mca-marines.org/wp-content/uploads/Expeditionary-Advanced-Base-Operations-EABO-handbook-1.1.pdf

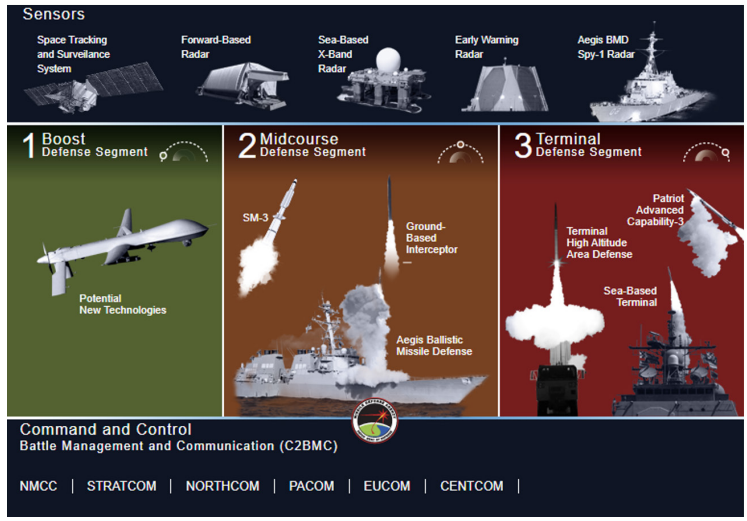
56 Jeremiah Rozman, *Integrated Air and Missile Defense in Multi-Domain Operations* (Arlington, VA: Association of the United States Army, June 2020), available at https://www.ausa.org/publications/integrated-air-and-missile-defense-multi-domain-operations.

57 Well over 80 percent of MDA's FY2018 budget was allocated toward ballistic missile defense. This figure was calculated by comparing MDA's total FY2018 budget for ballistic missile programs and comparing it with its total budget for non-ballistic threat programs. See Tom Karako and Wes Rumbaugh, "Analyzing the PB 2018 Missile Defense Agency Budget," *Center for Strategic and International Studies*, May 24, 2017, https://missilethreat.csis.org/analyzing-pb-2018-missile-defense-agency-budget/.

58 Jason Sherman, "SM-3 Block IIA Intercepts ICBM Target, Validating Potential For Homeland Defense 'Underlayer'," *Inside Defense*, November 17, 2020, https://insidedefense.com/daily-news/sm-3-block-iia-intercepts-icbm-target-validating-potential-homeland-defense-underlayer.

for leading the development of defenses against cruise missiles or UAVs, the agency's IAMD technical authority role has given it the ability to work across services to address all IAMD threats, not just ballistic missiles.

FIGURE 4: THE U.S. BALLISTIC MISSILE DEFENSE SYSTEM



Source: U.S. Missile Defense Agency

Defense against hypersonic missiles is a matter of increasing importance. Hypersonic refers to any missile or aircraft capable of Mach 5 or greater speeds. Although hypersonic weapons are not new (ICBMs and other classes of ballistic missiles fly well in excess of Mach 5), the new threats are represented by the growing proliferation of hypersonic cruise missiles and hypersonic glide vehicles (HGVs), both capable of high-speed penetration of air and missile defense systems. HGVs are typically launched into a suborbital trajectory followed by maneuvering descent back into the lower atmosphere. HGV's, because of their low altitude and maneuvering approaches, are more difficult to track and intercept than conventional cruise or ballistic missiles. Therefore, the critical concerns are capabilities (e.g., maneuverability—making trajectories unpredictable) and quantity.[59]

Intercepting hypersonic missiles is predicated on detecting and tracking them. Most ground-based radars cannot detect incoming hypersonic weapons until late in their flight profile. This stems from the capability of hypersonic vehicles to fly non-ballistic flight paths, leaving less time to intercept them compared to a traditional ballistic missile. The Spaced Based Overhead Infrared System (SBIRS) constellation can detect missile launches worldwide, but tracking fast, maneuvering targets remains challenging. One project underway

59 Abraham Mahshie, (January 19, 2022), "Hypersonics Defense," *Air Force Magazine*, https://www.airforcemag.com/article/hypersonics-defense/. See also Kelly Sayler, "Hypersonic Missile Defense: Issues for Congress," *Congressional Research Service* (CRS), August 21, 2023, https://crsreports.congress.gov/product/pdf/IF/IF11623.

to address that is the development of the Hypersonic and Ballistic Tracking Space Sensor (HBTSS), which supports fire control requirements for ballistic and hypersonic threats.[60] A more recent initiative has been the development of elements of a hypersonic missile defense system to defend against hypersonic weapons and other emerging missile threats.[61] MDA's current approach, begun in April 2021, is to initiate the Glide Phase Interceptor (GPI) and integrate it with the Aegis system, with an initial target timeframe of the mid-2020s—now slipping into the early 2030s. The Defense Advanced Research Projects Agency (DARPA) will also be supporting the effort.[62]

In 2018, *Inside Defense* reported that MDA could soon begin to test an advanced ballistic missile tracking system utilizing a long-endurance variant of the MQ-9 Reaper UAV. Equipped with non-radar sensors, this system could provide a capability against emerging threats that are designed to defeat radar-based tracking systems.[63]

Other, less publicized successes include MDA's consistent and significant contributions to Israel's IAMD, including the Arrow missile system, David's Sling, and Iron Dome air defense systems.[64] IAMD effectiveness is not just the technology and systems—it must also include doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P) areas, including the vital area of "T" (Training).[65] IAMD training is critical for tactical and operational effectiveness of the renowned Israel Missile Defense Organization (IMDO) and the Israeli Air Defense Command (IADC). The IADC was able to accomplish that using an Integrated Test-Bed (ITB) battle lab supporting IAMD training. This ITB was initially developed during the 1990s as part of the overall MDA effort with Israel to deploy and exercise the command and control of the Arrow missile system to defend Israel against foreign ballistic missiles.[66]

ITBs are invaluable tools for developing, refining, and exercising complex Integrated Air and Missile Defense Systems. ITBs offer unique opportunities for experimentation and development. They are also highly useful tools in formulating and instantiating the complex

60 Ibid.

61 Kelly M. Sayler and Stephen M. McCall, "Hypersonic Missile Defense: Issues for Congress," Congressional Research Service (2021), https://crsreports.congress.gov/product/pdf/IF/IF11623.

62 Ibid.

63 Rachel Karas, "MQ-9 Missile Defense Efforts Moving Toward Flight Tests," *Inside Defense*, August 23, 2018, https://insidedefense.com/insider/mq-9-missile-defense-efforts-moving-toward-flight-tests.

64 Missile Defense Agency (MDA), Fiscal Year (2024) Budget Estimates Overview, 2023, https://www.mda.mil/global/documents/pdf/MDA%20FY24%20Budget%20Booklet.pdf. See also MDA press releases for the Arrow Program support since 1996 at https://www.mda.mil/news/gallery_internationalcoop_arrow.html.

65 DOTMLPF-P—Doctrine, Organization, Training, Material (not the big acquisition items but spares, munitions, test sets, etc.), Leadership, Personnel, Facilities, and Policy.

66 Israel Defense, "Israel, US complete joint missile defense exercise," May 9, 2022, https://www.israeldefense.co.il/en/node/55698#:~:text=The%20Israeli%20Test-Bed%20%28ITB%29%20battle%20lab%2C%20developed%20by,that%20assist%20in%20comprehensive%20debriefings%20of%20the%20scenarios.

architectures needed for success in IAMD in addition to the near-real world exercise of IAMD tactics, techniques, and procedures (TTP). This capability would be vital to places like Guam, which will have enhanced IAMD with multiple sensors, C2, and effectors. The skilled personnel that are part of this IAMD and those that lead them need to practice and develop effective TTPs that could mean the difference between successful and unsuccessful active defense.

United States Navy

The U.S. Navy possesses the most developed layered, comprehensive, and distributed (due to ship mobility) IAMD of all of the services.[67] The Navy's surface combatants both possess self-defense capabilities as well as constituting the sea-based leg of MDA's efforts for ballistic missile defense. The Navy has more than some 90 surface combatants equipped with the Aegis Combat System (22 cruisers & 68 destroyers) and 47 Aegis BMD capable ships, including forward-based and forward-deployed ships in the Western Pacific.[68] The majority of Aegis BMD ships are equipped with SM-3 Block 1A & 1B, and there are a smaller number of the SM-3 Block IIA equipped ships that became operational in 2019.[69] These Aegis destroyer loadouts also include the SM-2 and the SM-6. These missiles combined with other ship systems provide a layered and comprehensive IAMD for ballistic missiles, cruise missiles, and a variety of air threats.

The Navy also has some of the world's best Battle Management Command and Control (BMC2), with the Cooperative Engagement Capability (CEC) and its Naval Integrated Fire Control Counter-Air (NIFC-CA) based on CEC and Link-16.[70] The Cooperative Engagement Capability provides a sensor network that improves situational awareness and enables advanced battle management CEC is a critical capability for any credible salvo defense, and it provides the best existing example of "any sensor, best shooter" capabilities.[71] CEC combined with NIFC-CA provides a model BMC2 for implementation of a layered,

67 The DoN also demonstrates certain characteristics of distributed defense by being mobile. However, some of the concepts do not correlate directly with land-based assets that are fixed. However, they could still distribute or disperse. Some combination of dispersal, mobility (road-mobile IAMD assets) and passive defenses is needed.

68 Missile Defense Project, "Aegis Ballistic Missile Defense," *Missile Threat*, Center for Strategic and International Studies, June 14, 2018, last modified August 4, 2021, https://missilethreat.csis.org/system/aegis/.

69 Japan Ministry of Defense, "Missile Defense," https://www.mod.go.jp/en/d_architecture/missile_defense/index.html; Missile Defense Project, "Standard Missile-3 (SM-3)," Center for Strategic and International Studies, last updated July 15, 2015, https://missilethreat.csis.org/defsys/sm-3/. The SM-3 IA and IB respectively represent the first and second generation of exo-atmospheric sea-based ballistic missile defense interceptors. They are designed to destroy short- to intermediate-range ballistic missiles during their midcourse phase.

70 Mallory Shelbourne, "Navy Testing Battle Management Aid on Aircraft Carrier," *USNI News*, November 26, 2020, https://news.usni.org/2020/11/26/navy-testing-battle-management-aid-on-aircraft-carrier. One of NIFC-CA's key capabilities is the elevated sensor the on E-2D which enables OTH engagements.

71 Janes IHS Markit, "Cooperative Engagement Capability," August 13, 2021.

comprehensive, and distributed defenses on land in conjunction with the USA's IBCS and other emerging technologies.[72]

The successful Aegis system has been adapted for BMD on-shore with the Aegis Ashore system. Currently, there is one operational Aegis Ashore in Romania, with a second site that will be fully operational in Poland in 2024[73] A number of Aegis destroyers will be upgraded with the Navy's next generation AN/SPY-6(V)1 Air and Missile Defense Radar that will address critical BMD and air defense capability gaps.[74]

United States Army and Marine Corps

DoD is largely dependent on the Army to organize, train, and equip its forces to provide land-based defenses against theater ballistic missiles and land-attack cruise missiles. Although the Army has made credible and evolutionary progress in enhancing theater IAMD capabilities in recent years, one critical area that has seen minimal progress is land-based cruise missile defense (CMD).[75] In addition, the posture and presence of IAMD has not kept pace with the threats and INDOPACOM requirements.

The Army's air and missile defense forces include approximately 60 batteries of Patriot Advanced Capability (PAC) low altitude air and missile defense systems all in the active component. Army Patriot battalions are equipped with PAC-3 and PAC-3 Missile Segment Enhancement (MSE) weapon systems or earlier generation PAC-2 Cost Reduction Initiative (CRI) family of interceptors.[76] Approximately 15 Army Patriot battalions currently operate ~60 batteries with ~360 launchers and more than 1,200 interceptors in total.[77] Although Patriot-equipped units are an effective element of the air and missile defense architectures of the United States and many of its allies, they are expensive and their combined capacity would be insufficient to protect air bases, ports, and other critical military infrastructure

72 CEC was developed first to connect Aegis ships with a particular sensor/weapon mix to do things like "Engage on Remote" in a particular way. Then NIFC-CA took it further with other sensors/weapons and added Link-16 capability that leverages CEC data.

73 Linda Hersey, "Poland-based Aegis Ashore missile defense moves toward full operation," May 10, 2023, https://insidedefense.com/daily-news/poland-based-aegis-ashore-missile-defense-moves-toward-full-operation.

74 Center for Strategic and International Studies, "Maritime Security Dialogue: The Aegis Approach with Rear Admiral Tom Druggan," November 22, 2021, https://www.csis.org/analysis/maritime-security-dialogue-aegis-approach-rear-admiral-tom-druggan.

75 Missile Defense Advocacy Association (MDAA), "Missile Defense in Ukraine: Proven Here, Proven Anywhere," Webinar Official Transcript, October 21, 2022, p. 3, https://missiledefenseadvocacy.org/wp-content/uploads/2022/10/Missile-Defense-in-Ukraine-Proven-Here-Proven-Anywhere-Full-Transcript-2.pdf.

76 Patriot systems have been sold to over 13 countries and will soon be operational in Poland.

77 Department of the Army, "Fiscal Year (FY) 2022 Budget Estimates, Volume I, Operation and Maintenance, Army, Justification of Estimates," May 2021, pp. 88, 102, https://www.asafm.army.mil/Portals/72/Documents/BudgetMaterial/2022/Base%20Budget/Operation%20and%20Maintenance/OMA_VOL_1_FY_2022_PB.pdf.

they would depend on during a major conflict with a great power.[78] Annual operations and support (O&S) costs for the Army's 15 Patriot battalions is approximately $800 million,[79] which does not include modernization costs or the cost of replacing missiles expended during training or operations.[80] Recent modernization of the PAC-3s continues to increase their effectiveness against MRBMs.[81]

The Army is upgrading its Patriot Air and Missile Defense system and developing the Integrated Air and Missile Defense Battle Command System (IBCS) to integrate its air and missile defense sensors, launchers, and command and control networks. IBCS was approved for low-rate initial production in January 2021.[82] IBCS achieved initial operating capability from the Army on May 1, 2023, and the system is ready for operational fielding. "IBCS will operate with air surveillance and fire control capabilities across the Army, Air Force, and Navy and with joint and multinational [air and missile defense] forces at all echelons…allows rapid convergence of sensor, shooter, and mission command components on an integrated fire control network," according to LTG Daniel Karbler, head of Army Space and Missile Defense Command.[83]

In addition, the Army is acquiring a new radar called the Lower Tier Air and Missile Defense Sensor (LTAMDS) to replace the aging AN/MPQ-65 PAC-3 legacy radars.[84] This new radar provides 360-degree capability with greater range and fidelity for the most advanced threats.[85] LTAMDS employment is enabled by IBCS (the fielding plans are linked) and will allow Patriot firing units to make use of the full kinematic capabilities of the PAC-3MSE

78 For example, the *Washington Post* reported a U.S. ally using a Patriot missile to defeat a small, inexpensive quadcopter in 2017. See Derek Hawkins, "A U.S. 'ally' fired a $3 million Patriot missile at a $200 drone. Spoiler: The missile won." *Washington Post*, March 17, 2017, https://www.washingtonpost.com/news/morning-mix/wp/2017/03/17/a-u-s-ally-fired-a-3-million-patriot-missile-at-a-200-drone-spoiler-the-missile-won/.

79 National Research Council, *Making Sense of Ballistic Missile Defense: An Assessment of Concepts and Systems for U.S. Boost-Phase Missile Defense in Comparison to Other Alternatives* (Washington, DC: The National Academies Press, 2012), pp. 266-273, https://www.nap.edu/catalog/13189/making-sense-of-ballistic-missile-defense-an-assessment-of-concepts. According to this report, O&S for each battalion is about $54 million in FY2010 dollars.

80 Government Accountability Office, *Weapon System Annual Assessment* (Washington, DC: GAO, April 2018), pp. 72-73, https://www.gao.gov/assets/700/691473.pdf. Patriot MSEs cost about $5.8 million each. Since 2018, the cost per missile has come down some but it has been only a marginal decrease in costs.

81 Jason Sherman, "PAC-3 armed with new software intercepts advanced medium-range ballistic missile target," *Inside Defense*, March 20, 2023, https://insidedefense.com/daily-news/pac-3-armed-new-software-intercepts-advanced-medium-range-ballistic-missile-target.

82 *Army Technology*, "US DoD approves US Army's new battle command system for production," January 15, 2021, https://www.army-technology.com/news/us-dod-us-armys-battle-command-system-production/.

83 Jason Sherman, "Army declares 'game-changing' IBCS operational, major milestone seven years late," *Inside Defense*, May 1, 2023, https://insidedefense.com/daily-news/army-declares-game-changing-ibcs-operational-major-milestone-seven-years-late.

84 U.S. Army and U.S. Air Force, "A Joint Strategy for Air Base Defense Against Missile Threats" [Interim Response], p. 8, Washington DC: CSA and CSAF, 2021 (not available to the public).

85 Missile Defense Advisory Alliance (MDAA), "Lower Tier Air and Missile Defense Sensor (LTAMDS)," July 24, 2020, https://missiledefenseadvocacy.org/defense-systems/lower-tier-air-and-missile-defense-sensor-ltamds/.

interceptors. The combination of LTAMDS and IBCS should bring about synergistic capabilities of Army systems.[86] This would mitigate the single points of failure, provide more comprehensive capabilities, and actually allow forces to be distributed or mobile. On the downside, these radars are expensive. There are other important radars that are aging as well that include legacy Sentinel A3 (AN/MPQ-64A3) air and missile defense radar.

A new version of the Sentinel radar system (AN/MPQ-64A4 or Sentinel A4) will provide a modern AESA radar with increased target identification, tracking, and classification with added electronic protection capabilities that will enhance coverage of the battlespace and will improve the ability of the Army's short-range air defenses (SHORAD) and IFPC 2-I to identify cruise missiles, UAS, guided rockets, artillery, mortars, and missiles (or G-RAMM),[87] and other threats.[88] To reduce the vulnerability of these two new radars (LTAMDS and Sentinel A4), the USA's Corps of Engineers Engineer Research and Development Center (ERDC) should design passive defenses (e.g., sensor shelters) and shelters for personnel and critical support equipment.

The Army also currently has seven batteries of Terminal High Altitude Air Defense (THAAD) ballisticmissile defense systems with 42 launchers and more than 500 interceptors in total.[89] THAAD is capable of intercepting ballistic missiles at endo- and exo-atmospheric altitudes during their last stage of flight.[90] The Army has said it has a requirement for nine batteries.[91] The United States has deployed THAAD batteries to Guam and South Korea, along with additional THAAD AN/TPY-2 radars to Japan, Turkey, and Israel.[92]

The Army's short-range air defense (SHORAD) forces consist primarily of seven battalions in the Army National Guard (ARNG) equipped with small, short-range Stinger surface-to-air missiles mounted on ground vehicles (i.e., Avengers). In the active component, SHORAD forces include two battalions of short-range Land-based Phalanx Weapon Systems (LPWS) to counter-RAM (or C-RAM) which also contain one battery each of Avengers. In addition,

86 U.S. Army and U.S. Air Force, "A Joint Strategy for Air Base Defense Against Missile Threats" [Interim Response], p. 8, Washington DC: CSA and CSAF, 2021 (not available to the public).

87 Christopher Bassler, Peter Kouretsos, and Harrison Schramm, "Frameworks for Assessing the Military Implications of Emerging and Disruptive Technologies" in 14th NATO Operations Research and Analysis Conference on Emerging and Disruptive Technology, 5 October 2020.

88 Janes IHS Markit, "US Army selects Lockheed Martin for new Sentinel radar," October 3, 2019; Janes IHS Markit, "AN/MPQ-64 Sentinel series," last updated November 4, 2021.

89 The International Institute for Strategic Studies, *The Military Balance* 121, February 24, 2021, pp. 31, 51.

90 Government Accountability Office, *Missile Defense: The Warfighter and Decision Makers Would Benefit from Better Communication about the System's Capabilities and Limitations* (Washington, DC: Government Accountability Office, 2018), pp. 85-90, https://www.gao.gov/products/gao-18-324.

91 Ibid., p. 89. The FY 2024 MDA budget is tentatively funding an 8th THAAD battery.

92 Missile Defense Advocacy Alliance (MDAA), "AN/TP-2 Radar," December 2018, https://missiledefenseadvocacy.org/defense-systems/armynavy-transportable-radar-surveillance-antpy-2/.

there are two Patriot composite battalions which each have one battery of Avengers. There are also three M-SHORAD Battalions.[93] The USA is in the process of acquiring two new SHORAD systems, Initial Maneuver-SHORAD (IM-SHORAD) and Indirect Fire Protection Capability (IFPC Inc 2-I). IM-SHORAD will protect divisions and BCTs from rotary wing aircraft, fixed wing aircraft, and UAS threats.[94] IFPC Inc 2-I's initial priority focus is defense against cruise missiles and UAS. Later versions of IFPC will include C-RAM capabilities, with high-energy lasers (HELs) and high-powered microwave (HPM) firing units.[95] The HEL portion could transition to a program of record as soon as FY2025.[96]

The Army is making significant changes to its current SHORAD force structure to accommodate the need for M-SHORAD and IFPC. Overall, there are plans for nine battalions of M-SHORAD force structure, but those plans are not fully funded.[97] Second, there will be a plan for nine battalions of IFPC 2-I force structure with details on funding unavailable.[98] In addition, there is no current information on active component/reserve component (AC/RC) mix of this force structure, which is critical to future posture and presence and vitally important if the forces need to move quickly into an AOR. Currently, the USA does not have the force structure and personnel to protect manuever units and commands (USA operating forces) while increasing capabilities to defend air bases and Pre-Positioned Sites (PPE) outside the CONUS—especially in the INDOPACOM AOR.[99] Of serious concern, IFPC Increment 2-I Block 1 has had numerous delays in its fielding from its inception.[100] The National Defense Authorization Act (NDAA) for Fiscal Year 2019 Report noted that the IFPC challenges would delay the Army's capability to defend air bases and other fixed locations

93 One M-SHORAD battalion (Germany) currently has Avengers and is fielding the M-SHORAD system. The other two (Fort Sill and Fort Hood) will field the M-SHORAD system in the next 18 months but do not currently have those systems (Source: USA SME).

94 Janes IHS Markit, "Counter UAS: Developing solutions to small, unmanned air threats," December 17, 2020.

95 "The U.S. Army's Indirect Fire Protection Capability (IFPC) System," Congressional Research Service, June 6, 2023, pp. 1-2, https://crsreports.congress.gov/product/pdf/IF/IF12421.

96 Dan Schere, "Army awards Lockheed Martin OTA worth up to $220M to develop IFPC high-energy laser prototype," *Inside Defense*, July 21, 2023, https://insidedefense.com/insider/army-awards-lockheed-martin-ota-worth-220m-develop-ifpc-high-energy-laser-prototype

97 USA and Air Force, "A Joint Strategy for Air Base Defense Against Missile Threats" [Interim Response], p. 8, Washington DC: CSA and CSAF, 2021. Not available to the public.

98 Ibid, p. 8.

99 This will be discussed later in this report. Congress has recognized this problem with the FY 2021 NDAA. See William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 116th Congress, H.R. 6395, Public Law 116-283, January 1, 2021, Section 156, p. 61.

100 Sydney J. Freedberg Jr., "SASC NDAA Would Add $500M for Cruise Missile Defense," *Breaking Defense*, June 7, 2018, https://breakingdefense.com/2018/06/sasc-ndaa-would-add-500m-for-cruise-missile-defense/. See also Government Accountability Office(GAO), *Weapon Systems Annual Assessment* (Washington, DC: GAO, June 2022), pp. 143-144, https://www.gao.gov/assets/gao-22-105230.pdf; GAO, *Weapon Systems Annual Assessment* (Washington, DC: GAO, June 2023), pp. 121-123.

against cruise missile attacks.[101] As a consequence, the FY2019 NDAA required the Army to field at least two batteries of cruise missile defenses by 2020 and two additional batteries by September 2023. However, the latter requirement was dropped in the FY2022 NDAA.[102]

The USA's current plans for IFPC 2-I have not progressed as quickly as intended and will delay the fielding of any significant Army cruise missile defense capability until the late 2020s.[103] After a shoot-off between Rafael and Dynetics, which focused on integration with IBCS, the Army recently chose Dynetics to produce the first 16 IFPC 2-I launcher (TELs) prototypes and 60 fieldable interceptor prototypes by the end of FY2023.[104] The primary interceptor will be Raytheon's AIM-9XB2, which is an IR-only missile.[105] FY 2023 congressional cuts will delay IFPC low rate initial production (LRIP) until FY2024.[106] However, the spirit and intent of the FY2019 NDAA requirements for cruise missile defense appear farther apart since IFPC will not deliver in sufficient quantities until well past FY2024.[107] The FY2023 appropriations showed no signs of IFPC ramp-up, nor did the FY2024 USA's budget plan.[108] On June 1, 2023, the IFPC delivery schedule was set into further disarray with the US Army "postponing a key assessment…by nearly a year" [to early FY2025] based on a delay from the manufacturer.[109]

The Army is continuing to consider several future novel and less costly means to defend against salvos as part of a "raid breaking" strategy, including command-guided

101 "While the Army continues to deprioritize IFPC, critical capabilities, such as cruise missile defense of fixed stations, are nonexistent." *The John S. McCain National Defense Authorization Act for Fiscal Year 2019 Report,* 115th Congress, 2nd Session, Report 115-262, p. 73, https://www.govinfo.gov/content/pkg/CRPT-115srpt262/pdf/CRPT-115srpt262.pdf.

102 *The John S. McCain National Defense Authorization Act for Fiscal Year 2019*, 115th Congress, 2nd Session, p. 25-26, https://www.govtrack.us/congress/bills/115/hr5515/text. See also Jason Sherman, "Army unshackled from requirement to buy, field additional Iron Dome batteries," *Inside Defense*, Jan 5, 2022, https://insidedefense.com/daily-news/army-unshackled-requirement-buy-field-additional-iron-dome-batteries.

103 Janes IHS Markit, "Bridging The Gap: US Tactical Short-Range Air-Defence Programmes," June 29, 2021. For additional information on IFPC delays, see CRS, "The U.S. Army's Indirect Fire Protection Capability (IFPC) System," June 6, 2023, https://crsreports.congress.gov/product/pdf/IF/IF12421

104 Ethan Sterenfeld, "Dynetics Wins Enduring IFPC Competition," *Inside Defense*, September 27, 2021, https://insidedefense.com/daily-news/dynetics-wins-enduring-ifpc-competition.

105 Ibid.

106 Ethan Sterenfeld, "Senate Bill Would Cut IFPC Prototype Funding," *Inside Defense*, October 26, 2021, https://insidedefense.com/insider/senate-bill-would-cut-ifpc-prototype-funding.

107 Jason Sherman, "Army Unshackled from Requirement to Buy, Field Additional Iron Dome Batteries," *Inside Defense*, January 5, 2022, https://insidedefense.com/daily-news/army-unshackled-requirement-buy-field-additional-iron-dome-batteries.

108 CRS, "The U.S. Army's Indirect Fire Protection Capability (IFPC) System," June 6, 2023, p. 2, https://crsreports.congress.gov/product/pdf/IF/IF12421

109 Ashley Roque, "Army Delays IFPC Inc 2 Program Operational Assessment to 'Early' FY25," *Breaking Defense*, June 1, 2023, https://breakingdefense.com/2023/06/army-delays-ifpc-inc-2-program-operational-assessment-to-early-fy25/. See also Mike Gallagher, Chairman, Select Committee on the Chinese Communist Party, "Letter to The Honorable Christine Wormuth," November 13, 2023, https://selectcommitteeontheccp.house.gov/media/letters/letter-army-secretary-defense-guam-chinese-missiles.

hyper-velocity projectiles (HVPs) that can be fired from cannon artillery like the 155mm Paladin self-propelled howitzer. It is also examining lower cost replacement surface-to-air interceptors for the PAC-3s.[110] In addition, work is still being done on gun-based systems, including rail guns and new cannon-based systems. These systems likely have the potential to increase magazine depth and reduce cost per kill against cruise missiles, UAS, and UAS swarms while being more expeditionary and mobile than current missile systems.[111]

Meanwhile, the USMC is pursuing a mobile variant of the Iron Dome system since the lack of a defense against cruise missiles and other aerial threats has been a critical capability gap. A design review in May 2021 approved a prototype of the system, also termed the USMC's Ground Based Air Defense (GBAD) Medium Range Intercept Capability (MRIC).[112] The GBAD MRIC tests for the system were successful in September 2022, and the USMC began the certification process in December 2022.[113] That will lead to a quick-reaction assessment in September 2024, with three batteries of systems produced in the FY25 to FY27 time-frame, and starting to field as early as FY26.[114] Importantly, the USMC is not wasting time acquiring the needed number of missiles for its operational GBAD MRIC batteries, already starting the process of procuring close to 2,000 Tamir missiles.[115] The USMC is also securing the production and sustainment of these missiles in the CONUS, which also benefits U.S.-Israeli cooperation.[116]

This GBAD MRIC will support the expeditionary advance base operations (EABO) concept following the 2018 NDS and Force Design 2030 guidance.[117] It will bring about a rebirth of USMC air defense capabilities—the first since the HAWK system[118] GBAD MRIC integrates

110 Joseph Trevithick, "The Army Now Wants Hypersonic Cannons, Loitering Missiles, And A Massive Supergun," *The War Zone,* April 3, 2018, http://www.thedrive.com/the-war-zone/19847/the-army-now-wants-hypersonic-cannons-loitering-missiles-and-a-massive-supergun.

111 Andreas Pogiatzi, "Northrop-Grumman: CBAD – Multilayered air defence with new-generation anti-aircraft projectiles," September 9, 2023, https://defenceredefined.com.cy/northrop-grumman-cbad-multilayered-air-defence-with-new-generation-anti-aircraft-projectiles/. This is one example, there are others.

112 Aidan Quigley, "Marine Corps announces successful Medium Range Intercept Capability test," *Inside Defense*, December 21, 2021, https://insidedefense.com/daily-news/marine-corps-announces-successful-medium-range-intercept-capability-test.

113 Nick Wilson, "Marine Corps Plans for MRIC Quick-Reaction Assessment in September 2024," *Inside Defense*, July 3, 2023, https://insidedefense.com/daily-news/marine-corps-plans-mric-quick-reaction-assessment-september-2024

114 Ibid.

115 Joseph Trevithick, "USMC Buying Nearly 2,000 Tamir Interceptors For Its Iron Dome Systems," *The War Zone,* August 25, 2023, https://www.thedrive.com/the-war-zone/usmc-buying-nearly-2000-tamir-interceptors-for-its-iron-dome-systems.

116 Nick Wilson, "Marine Corps Eyes Arkansas Site for Domestic Tamir Interceptor Production," *Inside Defense*, August 1, 2023, https://insidedefense.com/daily-news/marine-corps-eyes-arkansas-site-domestic-tamir-interceptor-production.

117 Johannes Schmidt, "Back to the Future: MRIC and the Rebirth of the Corps' Air Defense Capability," *USMC News*, July 27, 2023, https://www.marines.mil/News/News-Display/Article/3473524/back-to-the-future-mric-and-the-rebirth-of-the-corps-air-defense-capability/.

118 Ibid.

both EO-guided and RF-guided missiles in the same system. This combination provides greater capabilities against threats, especially in bad weather, and does so from a single platform (unlike the IFPC, which currently only has an IR missile). This would have the effect of reducing footprint while providing expanded capability in the field, given the need for day/night, all-weather air defense and a much lower cost than any other missile.[119]

United States Air Force and United States Space Force

Historically, the Air Force has maintained the core competency of "Air Superiority," both offensive counter-air (OCA) and defensive counter-air (DCA).[120] Nevertheless, the Air Force is "the only military service that lacks clear authority to develop and procure surface-based air and missile defense (AMD) systems to protect its own forces."[121] The Air Force has relied on Army air and missile defense (AMD) capabilities for active defense of air bases since decisions in the 1950s led to the Army owning both point and area defense, which "resulted in the Army owning all ground-based SAM and ballistic missile systems, whether for point or area defense."[122] Over the years, the Air Force and Army sparred over these roles and functions with no clear resolution, as detailed by a RAND report in 2020.

Current DOD guidance on the services' responsibilities to organize, train, and equip forces for air base defense is ambiguous at best. However, in September 2020, DOD Directive (DODD) 5100.01, "Functions of the DOD and its Major Components," specified the roles and functions of the services and other components. The DOD Directive directs all services to conduct "missile defense." In addition, it directs the Air Force to "conduct offensive and defensive operations, to include appropriate air and missile defense, to gain and maintain air superiority, and air supremacy as required, to enable the conduct of operations by U.S. and allied land, sea, air, space, and special operations forces."[123] It tasks the Army to "conduct air & missile defense to support the joint campaign."[124] However, there is no specific tasking to defend air bases, Pre-positioned Sites, or other vital assets that would be on a Critical Asset

119 Joseph Trevithick, "US Buying Nearly 2,000 Tamir Interceptors."

120 U.S. Air Force, "Air Force Doctrine Publication (AFDP) 3-01: Counterair Operations," last updated September 6, 2019, https://www.doctrine.af.mil/Portals/61/documents/AFDP_3-01/3-01-AFDP-D07-AIR-Execution.pdf.

121 Alan J. Vick, Sean M. Zeigler, Julia Brackup, and John Speed Meyers, *Air Base Defense: Rethinking Army and Air Force Roles and Functions* (Santa Monica, CA: RAND, 2020), p. 1, https://www.rand.org/pubs/research_reports/RR4368.html.

122 Ibid., p. 2.

123 *Department of Defense Directive 5100.01* (Washington, DC: DoD, 2020), https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dodd/510001p.pdf.

124 Ibid.

List (CAL) or a Defended Asset List (DAL). Senior DOD leadership was satisfied with DODD 5100.01 and recommended no further changes when it was reviewed in 2021.[125]

However, it appears that Congress took notice of the need to help resolve the ambiguity and responded with Section 156 of the FY2021 NDAA. That legislative language required the Air Force and Army to "jointly develop and carry out a strategy to address the defense of air bases and Pre-positioned Sites outside the continental United States…"[126] Although this report was due to Congress on June 1, 2021, as of mid-September 2023, there appears to be no public record of this final report except a recent public discussion of the report on August 29, 2023. Nevertheless, unofficial reports state that the Air Force has likely adopted (or accepted a more prominent role in) ground-based Air Base Air Defense (ABAD) as an official role and mission in conjunction with the Army.[127] However, the Air Force or the Army cannot do this alone—both must take action. In principle, that appears to be the de facto course of action (COA), according to the interim joint strategy by the CSAF and the CSA to address the defense of air bases and Pre-positioned Sites outside the CONUS.[128]

Given the magnitude of the threats, the Air Force will likely need to assume greater responsibilities for defending some of its theater expeditionary air bases even if the Army increases its capability, capacity, forward posture, and presence in the Indo-Pacific. However, it is unlikely that the Army will be able to significantly support active defenses at expeditionary bases (spoke bases in ACE operations) due to logistics and because dispersal will dilute the high-demand, low-density (or insufficient) air and missile defense forces. Nevertheless, the more likely focus will be additional main operating bases (MOBs) and some other additional sites. In addition, it requires the U.S. to proactively work with our allies and partners to contribute IAMD assets into combined IAMD organizations as outlined in INDOPACOM's *Integrated Air and Missile Defense Vision 2028* and beyond.[129]

125 Mitchell Institute for Aerospace Studies, panel discussion on "Operational Imperative Series: Resilient Basing, Sustainment and Communications," YouTube Video, August 30, 2023, https://www.airandspaceforces.com/air-force-army-air-defense-distributed-operations/. See also John A. Tirpak, "Air Force and Army Collaborate on Air Defense That's Cheaper for the Indo-Pacific, *Air & Space Forces Magazine*, August 29, 2023, https://www.airandspaceforces.com/air-force-army-air-defense-distributed-operations/. The panel confirmed the existence and key elements of the U.S. Army and U.S. Air Force, "A Joint Strategy for Air Base Defense Against Missile Threats" [Interim Response], Washington DC: CSA and CSAF, 2021 (not available to the public).

126 *William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021*, 116th Congress, H.R. 6395, Public Law 116-283, January 1, 2021, Section 156, p. 61.

127 John A. Tirpak, "Air Force and Army Collaborate on Air Defense That's Cheaper for the Indo-Pacific, August 29, 2023. See also Amy Hudson, "Defending Bases Forward," *Air and Space Forces Magazine*, March 26, 2021, https://www.airandspaceforces.com/article/defending-forward-bases/.

128 Ibid. This de facto COA is consistent with Alan J. Vick, et al., *Air Base Defense: Rethinking Army and Air Force Roles and Functions*, 2020. However, the history of air base joint strategy measures and even strategies with an MOU have been unsuccessful.

129 Col Lynn "Riddler" Savage, USAF, "USPACOM's Integrated Air and Missile Defense Vision 2028: Integrated Deterrence toward a Free and Open Indo-Pacific, *Journal of Indo-Pacific Affairs,* https://www.airuniversity.af.edu/JIPA/Display/Article/2915508/us-indopacoms-integrated-air-and- missile-defense-vision-2028-integrated-deterre/.

The significant change for the Air Force will likely be the acquisition and operation of some ground-based air and missile point defense in Air Base Air Defense.[130] These point defenses would likely occur at mostly non-MOB and expeditionary dispersal bases affiliated with the ACE concept. The Air Force will likely focus on ground-based point defense against cruise missiles and UAS.[131] Nevertheless, it is critically important that any future Air Force point defense capabilities be interoperable and complementary with Army, Navy, USMC, and key allied IAMD capabilities—with BMC2 playing a critical role in facilitating that integration. Not unrelated to these changes, in August 2022, Deputy Secretary Hicks announced that the Air Force would be the "acquisition authority with respect to capabilities to defense the homeland against cruise missile threats…"[132]

The USSF is becoming increasingly important as space superiority is critical for the nation and IAMD. In fact, some space trailblazers believe the IAMD name should change to ISAMD (Integrated Space, Air and Missile Defense). As part of space superiority, the most important role and mission for the USSF is its missile strategic warning and tracking missions. The rise of the Space Force likely gave impetus to POTUS signing a new Unified Command Plan (UCP) that moved global missile defense operational support responsibilities from STRATCOM to SPACECOM on April 25, 2023.[133] The UCP will allow SPACECOM to implement a "trans-regional missile defense" concept that will be able to "effectively integrate and fuse data for rapid detection, characterization, tracking and dissemination so that Joint Force commanders can defeat the threat."[134] Lt Gen Daniel Karbler, Commander, USA Space and Missile Defense, argues that missile defense is really trans-regional—not global. In addition, he emphasizes the importance of U.S. allies and partners for missile defense. Missile defense interceptors are regional because they belong to combatant commanders—there are no global interceptors.[135]

130 The assumption is that "A Joint Strategy for Air Base Defense Against Missile Threats" is implemented from Section 156 of the FY2021 NDAA. It is assumed that air-based point defenses (e.g., UAS with HEL/HPM/EW) are within the latest understanding of Air Force roles and missions or roles and functions. For the ABAD program, see https://www.parsons.com/2021/07/parsons-to-lead-953m-ceiling-effort-to-protect-u-s-air-force-air-bases/.

131 Mitchell Institute for Aerospace Studies, panel discussion on "Operational Imperative Series: Resilient Basing, Sustainment and Communications," YouTube Video, August 30, 2023.

132 Jason Sherman, "Hicks breaks bureaucratic logjam, taps Air Force to lead homeland cruise missile defense," *Inside Defense*, August 1, 2022, https://insidedefense.com/share/215582.

133 Jason Sherman, "Biden Approves Shift of Global Missile Defense Ops Support from STRATCOM to SPACECOM," *Inside Defense*, May 16, 2023, https://insidedefense.com/daily-news/biden-approves-shift-global-missile-defense-ops-support-stratcom-spacecom.

134 Maj Gen Michale Morrissey, SPACECOM director of policy and planning. Apurva Minchekar, "SPACECOM Benefitting from Transregional Missile Defense Concept," *Inside Defense*, August 11, 2023, https://insidedefense.com/daily-news/spacecom-benefitting-trans-regional-missile-defense-concept

135 Cecil Longino, Space and Missile Defense Command Public Affairs, "Karbler Explains Trans-Regional Missile Defense Concept," June 7, 2023, https://www.theredstonerocket.com/military_scene/article_ab53e886-04d4-11ee-9685-eb10a5a9bdb1.html.

Several of the critical capabilities that the USSF manages for regional IAMD are missile warning and tracking. The programs that execute these functions include the SBIRS today and the Next-Gen Overhead Persistent Infrared (OPIR) system beginning in mid-decade. In addition, as discussed in the MDA section of this report, the USSF will be operating the Hypersonic and Ballistic Tracking Space Sensors, or HBTSS—critical to hypersonic defense. In addition, USSF's presence in the space domain is critical for IAMD because of the reliance of both friendly and enemy forces on space-based sensors, PNT, and communication to conduct missile attacks. The importance of space power capabilities for missile defense cannot be overstated, as missile warning and tracking are sine qua non for effective IAMD of emerging threats (e.g., HGVs).[136]

Joint Integrated Air and Missile Defense Organization (JIAMDO)

The Joint Integrated Air and Missile Defense Organization (JIAMDO) is aligned under the Joint Staff J-8 and is chartered to "plan, coordinate, and oversee Integrated Air and Missile Defense (IAMD) requirements, joint operational concepts, and operational architectures."[137] As such, J8-JIAMDO had programmatic and functional responsibility for some essential missile defense programs across the Department of Defense. For example, J8-JIAMDO had the Black Dart Counter UAS (C-UAS) Technical Demonstration program in cooperation with the Defense Innovation Unit (DIU) until 2019.[138] J8-JIAMDO also operates Nimble Fire, an IAMD operator-in-the-loop modeling and simulation capability. Separately, the Cruise Missile Combat Identification program is underway to examine requirements for identification technologies.

Because of the importance of developing and operating layered, comprehensive, and distributed air and missile defense systems, J8-JIAMDO is also conducting a program identified as the Joint Regional Integrated Air and Defense Capability Mix (JRICM). This program aims to determine the effectiveness of IAMD to defeat or degrade adversary air and missile attacks.[139] J8-JIAMDO's role in the Department is unique and critically important for the future of theater IAMD by having the across-the-board role of coordinating the nation's

136 Congressional Research Service (CRS), Hypersonic Missile Defense: Issues for Congress, August 21, 2023, https://crsreports.congress.gov/product/pdf/IF/IF11623

137 The Joint Staff, "Department of Defense Fiscal Year (FY) 2021 Budget Estimates, Defense-Wide Justification Book Volume 5 of 5: Research, Development, Test & Evaluation, Defense-Wide," February 2020, available at https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/budget_justification/pdfs/03_RDT_and_E/TJS_PB2021.pdf.

138 Black Dart is a "joint interagency demonstration focusing on rapid development and implementation of C-UAS technology from readily-available commercial and government vendors." Defense Innovation Unit, "DIU Supports Counter Drone 2 Evaluation of C-UAS Technology," January 15, 2020, https://www.diu.mil/latest/diu-supports-counter-drone-2-evaluation-of-c-uas-technology.

139 Office of the Secretary of Defense, "Department of Defense Fiscal Year (FY) 2021 Budget Estimates, Defense-Wide Justification Book Volume 3 of 5: Research, Development, Test & Evaluation, Defense-Wide," February 2020, https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2021/budget_justification/pdfs/03_RDT_and_E/RDTE_Vol3_OSD_RDTE_PB21_Justification_Book.pdf.

missile defense programs. J8-JIAMDO has more of niche role compared to MDA which focuses mostly missile defense capabilities. However, J8-JIAMDO provides independent assessment of missile defense capabilities and gaps.[140] In addition, the authors believe JIAMDO plays the important role of honest broker.

Joint Counter-Small UAS Office (JCO)

In the last several years, there have been several noteworthy attacks by UAS worldwide, especially against unprotected assets.[141] These include the 2019 attack on Saudi Arabia's Abqaiq oil facility,[142] the 2020 war in Azerbaijan,[143] and the ongoing war in Ukraine.[144]

In January 2020, DOD made the Army the executive agent for sUAS (Class 1-3) threats and established the Joint C-sUAS Office (JCO), which leads, synchronizes, and directs C-sUAS activities to ensure unity of effort across the Defense Department.[145] The establishment of JCO acknowledged that there is an ongoing UAS/C-UAS arms race, and that standard processes will not suffice. For class 4-5 UAS threats, the Air Force was selected as the executive agent.[146]

The JCO is "to lead and direct associated doctrines, requirements, materials, and training aspects while the Army's Rapid Capabilities and Critical Technologies Office (RCCTO) was assigned to be the JCO's material and acquisition lead."[147] The JCO has evaluated several capabilities, made some approved recommendations, and has identified ten interim technologies. For fixed/semi-fixed defense, the JCO approved these three systems in 2021:[148]

- The U.S. Army's Fixed Site-Low, Slow, Small Unmanned Aircraft System Integrated Defeat System (FS-LIDS). This system includes a variety of elements, including several radars, DF sensors, an EO/IR camera, a control center for manned personnel, and interceptors.

140 Gabriel Almodovar, Daniel Allmacher, Morgan Ames III, and Chad Davies, Joint Integrated Air and Missile Defense: Simplifying an Increasingly Complext Problem, *Joint Forces Quarterly*, 1st Quarter 2018, pp. 81-82, https://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-88/jfq-88_78-84_Almodovar-et-al.pdf?ver=2018-01-09-102341-613.

141 David Hambling, "Failing To Learn: Why Russia's Air Bases Keep Getting Hit By Cheap Drones From Ukraine," *19FortyFive*, August 22, 2023, https://www.19fortyfive.com/2023/08/failing-to-learn-why-russias-air-bases-keep-getting-hit-by-cheap-drones-from-ukraine/.

142 James Poss, "The Unsurprising Surprise Iranian Drone Attack On Oil," *Inside Unmanned Systems*, October 30, 2019, https://insideunmannedsystems.com/the-unsurprising-surprise-iranian-drone-attack-on-oil/.

143 Janes IHS Markit, "Clear skies: Pentagon Hones Strategies for Counter-UAS Technology," December 30, 2021.

144 Carl Rehberg, "Integrated Air and Missile Defense: Early Lessons From the Russia-Ukraine War," *19FortyFive*, June 10, 2022, https://www.19fortyfive.com/2022/06/integrated-air-and-missile-defense-early-lessons-from-the-russia-ukraine-war/.

145 Janes IHS Markit, "The Miniaturization of unmanned aerial warfare", PowerPoint Intelligence Briefing, January 26, 2021.

146 To date (September 2023), there has been no public briefings, or documentation on what the USAF is doing in this area.

147 Janes IHS Markit, "Clear skies: Pentagon hones strategies for counter-UAS technology," December 30, 2021.

148 Ibid.

- The Air Force's Negation of Improvised Non-State Joint Aerial Threats (NINJA).
- The Navy's Counter-Remote Control Model Aircraft Integrated Air Defense Network (CORIAN).

In the critically important area of C2, the JCO selected the following:[149]

- Forward Area Air Defense Command & Control (FAAD-C2) system, the USMC's Air Defense Systems Integrator (ADSI), and the Air Force's Multi-Environmental Domain Unmanned Systems Application (MEDUSA).

The JCO has established a reputation of action when it comes to active defenses for sUAS threats. Most of those actions have resulted in the JCO encouraging industry to develop a plethora of innovative capabilities to mitigate or eliminate sUAS. The JCO has focused on culling successful active defenses and has done that task well. However, this has led to limited success of the services, rapidly acquiring cost-effective capabilities and getting them to the warfighter (not part of the JCO charter). Nevertheless, active defenses will not stop all threats or 100% of a salvo or swarm—there will be leakers even with the best system(s).

149 Ibid.

CHAPTER 3

Toward Comprehensive IAMD

Current IAMD plans that rely on existing defensive interceptors cost too much, deliver too little, and do not sufficiently address the growing threat of massed (or salvo) air and cruise missile attacks.[150] This chapter presents an alternative approach: a layered, comprehensive, and distributed IAMD concept focused on addressing the full spectrum of threats. Specifically, the concept developed below is built around three concentric rings (or layers): an outer ring that can detect and engage hostile targets far beyond the range of ground-based defensive systems located at or near a threatened base; an inner ring that can protect the area immediately surrounding that base; and a close-in ring that provides point defense against specific targets on that base. These concepts are illustrated with an application for the future Defense of Guam.

Concepts for a Future Salvo Defense of Theater Bases

The Outer Ring

An outer defense network would mainly be comprised of sensors for early detection of incoming threats but would also include some weapons to reduce the size of enemy salvos.[151] Additionally, systems that make up the outer ring would target enemy aircraft and maritime vessels (surface and undersea) before they can launch long-range munitions.

150 See Carl Rehberg and Mark Gunzinger, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases* (Washington, DC: Center for Strategic and Budgetary Assessments, 2018), pp. 31-34. Air Force Institute of Technology (AFIT) research has confirmed these cost issues regarding cruise missile defense and the need for innovative solutions with this trailblazing research. Andrew R. Davis, "A Quantitative Argument For Autonomous Aerial Defense Over Embedded Missile Systems to Thwart Cruise [Missile] Threats," (Wright-Paterson Air Force Base, Ohio: Air University, 2021), https://scholar.afit.edu/cgi/viewcontent.cgi?article=6070&context=etd.

151 This report assumes the space sensor network but extensive details of those aspects are beyond the scope of this report.

FIGURE 5: ILLUSTRATION OF A POTENTIAL BASE "OUTER" SALVO DEFENSE RING

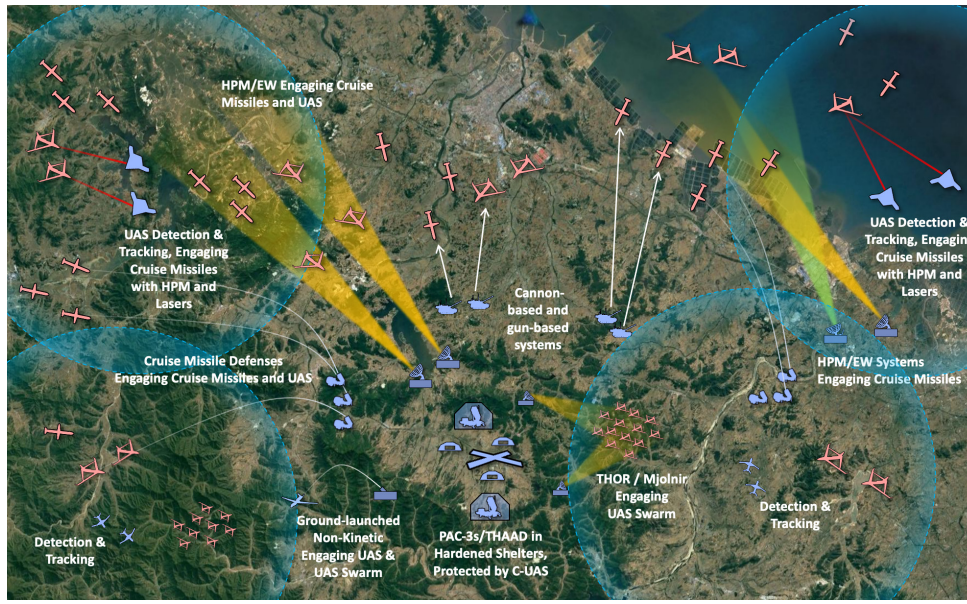
Source: Graphic created by CSBA.

Because the outer layers must be able to locate threats over the horizon from a targeted facility, it would rely on crewed and uncrewed airborne systems with persistence (e.g., HALE UAS) and space-based sensors in most cases. A battle management system that integrates information from multiple airborne, space, and land- and sea-based sensors would increase the probability of detecting and tracking threats (including salvos) in time to cue a distributed network of interceptors. This extended sensor network should have enough depth to detect missile launches and the paths of enemy aircraft, ships, and underwater vehicles before they launch their weapons. Secure datalinks should connect this network with the CEC sensors and network(s), IBCS sensor networks (and future JADC2 networks) to share information rapidly with sensors and shooters across the outer and inner rings of base defenses.[152] Critically important is the need to also link to Navy, Army, and Air Force multi-domain sensors and those of our vital allies and partners.

152 NIFC-CA (based on CEC and Link 16) integrates counter-air operations between the Navy's Aegis ships, E-2D early warning aircraft, and other airborne and sea-based sensors. See Congressional Research Service, "Navy Network-Centric Warfare Concept: Key Programs and Issues for Congress," April 12, 2007, https://crsreports.congress.gov/product/pdf/RS/RS20557/12.

The Inner Ring

FIGURE 6: ILLUSTRATION OF A POTENTIAL "INNER" SALVO DEFENSE RING



Source: Graphic created by CSBA.

The inner ring, by contrast, would be the first layer of defense under the control of the base itself. However, all these rings would overlap with sensor and effector coverage to maintain continuous threat tracks and provide more seamless engagement opportunities. Specifically, the inner ring would include extended range, ground-based and some airborne sensors and shooters; both kinetic and non-kinetic weapons; and hardened shelters to protect critical assets such as aircraft, munitions, IAMD assets (e.g., radars, TELs), and command and control systems.

In Figure 7, above, the base is under attack by both UAS and sUAS armed swarms and cruise missiles. The enemy drones attack the base on multiple axes across a 180-degree arc from the north to dissipate the defenders' capabilities. While the base has hardened facilities to protect aircraft and munitions, these facilities remain vulnerable to concrete penetrating munitions while the runways and taxiways are vulnerable to cratering and other munitions. Some air and missile defense assets might be compelled to remain in hardened shelters instead of exposing themselves to swarms of UAS and other threats.

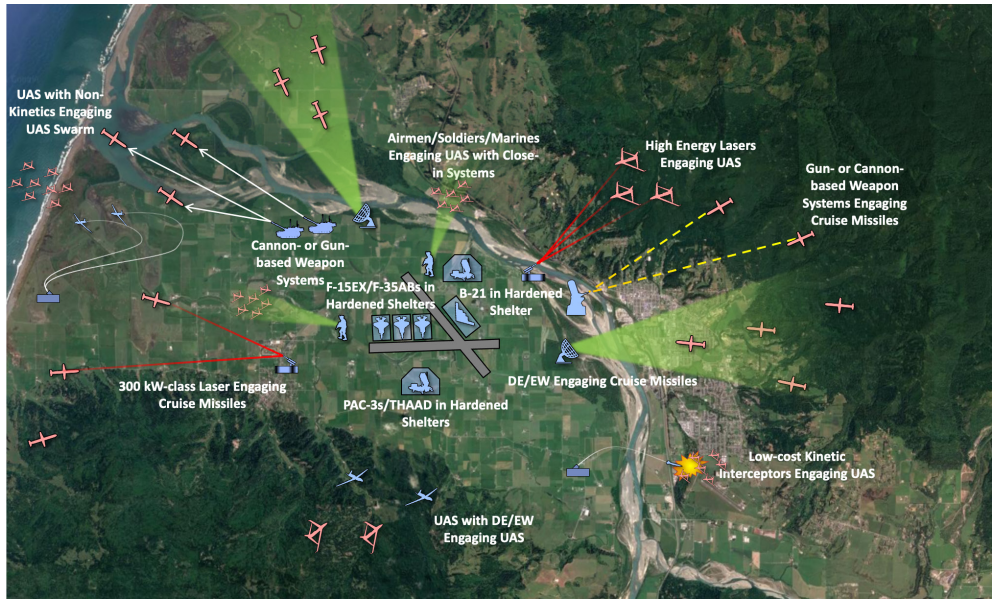
Similar to the outer defense concept, an inner base defense would require a sensor and communications network capable of detecting multiple threats and sharing a common picture of the battlespace across the complex. This network should include DoD's existing and planned space-based sensors, airborne sensors, and long-range ground-based radars to detect and provide early warning of incoming raids and salvos, as well as fire control radars. Inner and outer base defenses should be linked by BMC3 systems capable of coordinating

sensor and shooter operations.[153] However, new BMC3 systems and links are needed for theater ballistic and non-ballistic air and missile defense.

Figures 6 and 7 illustrate how orbits of UAVs equipped with 150 kW-class HELs (or HPM/EW capabilities) could support an inner ring salvo defense. CAPs of UASs with HELs (or HPM/EW capabilities) could deploy on different axes from a base to counter individual or swarms of incoming UASs, salvos of cruise missiles, and other air-launched PGMs. UAV HELs (or HPM/EW capabilities) would have several advantages compared to ground-based laser defenses located on or close to a base. Compared to ground-based lasers with similar design characteristics, airborne HELs would have increased slant ranges due to their altitudes and the advantage of operating in less dense and particulate-laden atmospheres. Moreover, if the geometry is favorable, UAS HELs (or HPM/EW capabilities) could attack cruise missiles and other threats, as depicted in Figures 6 and 7.

The Close-In Ring

FIGURE 7: ILLUSTRATION OF A CLOSE-IN BASE SALVO DEFENSE RING



Source: Graphic created by CSBA.

Finally, the close-in ring would be the last line of defense, protecting point targets that remain vulnerable to missiles and UAS that penetrate the outer and inner rings. The base close-in defenses could rely more heavily on non-kinetic defeat mechanisms than the outer layer. Notably, High Energy Lasers (HEL) and electromagnetic weapons (i.e., HPM/EW),

153 The BMC3 term used here is a generic term (not a specific program) without reference to current or future systems.

mixed with gun/cannon-based systems could play critical roles in the close-in air and missile defense battle.

For instance, the Army completed its Directed Energy SHORAD laser weapon "shoot-off" at Fort Sill in 2021. Competing contractors simulated the engagement of various targets, including UAS, rockets, artillery, and mortars. 50-Kw laser weapons were used, and the Army is acquiring two 300-Kw class laser prototypes with its IFPC capability for testing by 2025.[154] A 300-Kw class HEL could channel enough energy to defeat an incoming cruise missile.[155] HELs can also damage or destroy UAS sensors and other vital systems. IFPC-HPM could damage or destroy swarms of sUAS and other threats.

HPM/EW weapons use electromagnetic energy to damage or disrupt sensors, guidance systems, and other electronic systems by inducing currents that exceed the tolerances of targeted subcomponents.[156] Future HPM defenses could have longer ranges than short- to medium-range (up to 30 nm) kinetic air and missile defenses. A single HPM/EW weapon integrated with a ground vehicle or modified transportable container similar to "Conex" boxes could counter multiple cruise missiles, swarms of UASs, and other threats in an enemy salvo. Unlike kinetic weapons and lasers, HPM/EW defenses can simultaneously target multiple threats within their beamwidth. As shown in Figures 6, 7, and 8, HPM/EW emitters could be located around a base to provide 360-degree threat coverage while minimizing the potential that an HPM beam would create collateral damage to friendly electronic systems. To significantly increase IAMD cost-effectiveness (and minimize collateral damage), these capabilities must be placed on UAS. This shift would provide a significant advantage for the U.S. partners and allies in salvo competitions with adversaries by more easily providing this capability in layers. It also allows for comprehensive and distributed capabilities. The distributed capability reduces risk by avoiding concentration of critical assets in a small area while having mobility capabilities. The use of non-kinetic air and missile defense weapons obviates the need to stockpile and protect surface-to-air missiles.

Developing an Enhanced Integrated Air and Missile Defense for Guam

In December 2002, President George W. Bush released the National Security Policy Directive (NSPD-23) that directed the start of regional air and missile defense—stating

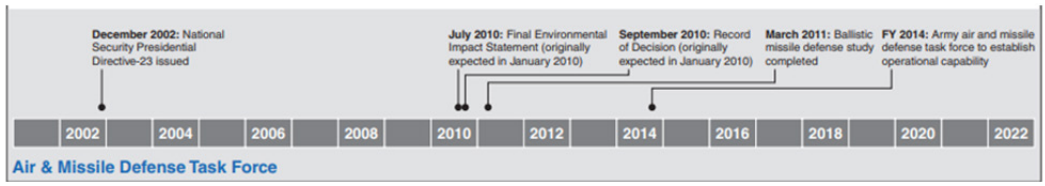
154 Jason Sherman, "DOD orders prototype 300-Kw lasers to test new cruise missile killing capability for Army," *Inside Defense*, October 10, 2023, https://insidedefense.com/daily-news/dod-orders-prototype-300-kw-lasers-test-new-cruise-missile-killing-capability-army%C2%A0. The USA has one 300-Kw laser demonstrator but will have two prototypes for the FY-2025 test campaign.

155 Jared Keller, "The Army's First Laser Weapon Is Almost Ready for a Fight," *Task & Purpose*, August 12, 2021, https://taskandpurpose.com/military-tech/army-laser-weapon-stryker-combat-shoot-off/.

156 HPM weapons could be capable of achieving a larger number and possibly more effective range of effects on targets if details are known about the targets' designs and vulnerabilities. See U.S. Air Force, "Fact Sheet: High Power Microwave Weapons," http://www.de.afrl.af.mil/pa/factsheets; and "US Air Force Moves Forward with High-Power Microwave Weapon," *Defense Update,* May 16, 2015, http:// defense-update.com/20150516_champ.html#.VijFhdadLzI.

clearly that DoD "…shall develop and deploy missile defenses capable of protecting not only the United States and our deployed forces, but also friends and allies…"[157] For Guam, preliminary studies and plans moved forward in the Joint Guam Military Master Plan until about 2011 (Figure 9) and then seemed to disappear until the Defense of Guam in the Pacific Deterrence Initiative (PDI) emerged.[158]

FIGURE 8: ORIGINAL GUAM MISSILE DEFENSE TIMELINE[159]



Source: GAO

In 2020 and 2021, then-INDOPACOM Commander Admiral Philip Davidson publicly advocated an Aegis Ashore system for Guam and highlighted the limitations of THAAD, given threats from China.[160] Admiral John Aquilino, who succeeded Davidson as INDOPACOM Commander in April 2021, reiterated Guam's strategic importance to the United States and the need to defend the island and to operate from it.[161] Admiral Davidson believed that this capability needed to be operational no later than 2026 and held to this requirement until his retirement in 2021. However, Admiral Aquilino seems to have hedged somewhat on an exact timeframe.[162] Nevertheless, both INDOPACOM commanders put the Defense of Guam as their #1 priority with critical China threat concerns this decade. Admiral

157 White House, National Policy on Ballistic Missile Defense (NSPD-23), White House Fact Sheet, May 20, 2003, https://irp.fas.org/offdocs/nspd/nspd-23-fs.htm.

158 A detailed history of the missile defenses for Guam is beyond the scope of this report. However, it is critical to have some context regarding defending Guam by ground-based missile defenses. There is no open-source information on much of this timeline.

159 Government Accountability Office (GAO), *Military Buildup on Guam: Costs and Challenges in Meeting Construction Timelines*, GAO-11-459R (Washington, D.C: GAO, 2011), Figure 2 (adapted), p. 8, https://www.gao.gov/assets/gao-11-459r.pdf.

160 Jason Sherman, "Pentagon Considers INDOPACOM Gambit to Replace THAAD with Aegis Ashore on Guam", *Inside Defense*, January 28, 2020, https://insidedefense.com/daily-news/pentagon-begins-work-aegis-ashore-guam; Joe Gould, "'Guam is a target today.' Pacific chief pitches Aegis Ashore to Congress," *Defense News*, March 9, 2021, https://www.defensenews.com/congress/2021/03/09/guam-is-a-target-today-pacific-chief-pitches-aegis-ashore-to-congress/.

161 "Our View: Defense of Guam Remains Top Priority for Indo-Pacific Command," *Pacific Daily News*, June 29, 2022, https://www.guampdn.com/opinion/our-view-defense-of-guam-remains-top-priority-for-indo-pacific-command/article_9dd29e1c-f6a4-11ec-91fc-7b116582e594.html.

162 Jason Sherman, "2026 Target for INDOPACOM's No. 1 Priority, Guam Defense System, Appears to be Slipping," *Inside Defense*, December 5, 2021, https://insidedefense.com/daily-news/2026-target-indopacoms-no-1-priority-guam-defense-system-appears-be-slipping.

Aquilino said, "U.S. forces must be prepared to defend Taiwan before 2027."[163] Therefore, defending Taiwan likely requires a fully operational Guam Defense System. According to John Hill, Deputy Assistant Secretary of Defense for Space and Missile Defense Policy, "…the defense of Guam…will simultaneously protect U.S. forces and our ability to project power in the region."[164]

Since the Spring of 2021, the Guam Defense System (sometimes labeled the Defense of Guam in the press) has been moving along with significant attention but without much public information.[165] In 2023, after years of discussing needed active defenses for Guam, it may be "set to become [the] most densely protected place anywhere on the planet."[166] Although several plans for air and missile defense for Guam have been proposed and there have been revisions, the exact details of the final architecture remain unclear. Nevertheless, much information was released in mid-2023 after the Environmental Impact Study information was made public.[167] The current peacetime (day-to-day) Guam missile defense consists of one THAAD battery deployed permanently to Guam (with an AN/TPY-2 radar) and Aegis-equipped Navy ship(s) used as needed, according to the GAO. This Guam baseline for active defenses falls well short of requirements.[168]

Initially, the Defense of Guam plan was to add Aegis Ashore only. However, there are limitations to such an approach without modifications. For instance, Aegis Ashore installations in Poland and Romania are optimized for only a limited number of ballistic missiles (not salvos) from Iran.[169] Nevertheless, similar to Aegis ships, a modified Aegis Ashore system for

163 Nick Wilson, "INDOPACOM commander stresses urgency in delivery of deterrent capabilities," *Inside Defense*, July 19, 2023, https://insidedefense.com/daily-news/indopacom-commander-stresses-urgency-delivery-deterrent-capabilities.

164 John Hill, Deputy Assistant Secretary of Defense for Space and Missile Defense Policy, Written Testimony for the House Armed Services Committee Strategic Forces Subcommittee Fiscal Year 2024 Budget Request for Missile Defeat and Defense Programs April 18, 2023, p. 5, https://insidedefense.com/sites/insidedefense.com/files/documents/2023/apr/04192023_bmd1.pdf.

165 Jason Sherman, "DOD Sends Congress Classified Blueprint for Potential Guam Defense System," *Inside Defense*, October 29, 2021, https://insidedefense.com/daily-news/dod-sends-congress-classified-blueprint-potential-guam-defense-system.

166 Joseph Trevithick, "Guam's Airspace Set To Be Most Defended On Earth In New Plans," *The War Zone*, August 11, 2023, https://www.thedrive.com/the-war-zone/guams-airspace-set-to-be-most-defended-on-earth-in-new-plans.

167 Jason Sherman, "DOD Eyes 20 Potential Guam Sites to Disperse Sensors, Control Center, Missile Launchers," *Inside Defense*, May 8, 2023, https://insidedefense.com/daily-news/dod-eyes-20-potential-guam-sites-disperse-sensors-control-center-missile-launchers. For the links to the EIS primary documents see https://insidedefense.com/document/mda-notice-guam-bmd-eis.

168 Government Accounting Office (GAO), *Missile Defense: Annual Goals Unmet for Deliveries and Testing*, (Washington, DC, GAO, May 2023), Table 8, p. 39, https://www.gao.gov/assets/gao-23-106011.pdf.

169 FY2024 NDAA language would upgrade the two European Aegis Ashore sites for Russian threats. See Jason Sherman, "DOD, NATO Exploring Expanded Mission for Aegis Ashore Sites in Europe: Countering Russia," April 18, 2023, https://insidedefense.com/daily-news/dod-nato-exploring-expanded-mission-aegis-ashore-sites-europe-countering-russia.

Guam could address some cruise missile threats by including the SM-6 missiles.[170] Second, Aegis Ashore does not appear to have sufficient passive defenses against potential attacks from a complex salvo environment.[171] Third, this approach may not provide adequate tools for low-cost cruise missile defense for complex salvos.[172] Although the SM-6 has the capability to provide cruise missile defense, it is a highly capable and expensive missile that will likely be needed to defeat other, more sophisticated, threats (e.g., some terminal capability against hypersonic threats).[173]

The current plan employs a disaggregated and partially mobile version of the Aegis Ashore system (a virtualized Aegis) and the Army's Strategic Mid-Range Fires (SMRF) or Typhon missile system.[174] Both of these systems are very likely central to the plans for the future Defense of Guam.[175] However, the mix of ground-based Mark 41 Vertical Launch Systems (VLS) and SMRF systems remains to be determined.[176]

170 RADM (ret) Mark Montgomery, "Taiwan and China: The Missile Defense Challenge" MDAA Webinar and Transcript, Sept 1, 2022, pp. 11-14, https://missiledefenseadvocacy.org/wp-content/uploads/2022/09/Taiwan-and-China-The-Missile-Defense-Challenge.pdf

Some of Guam's vulnerabilities could be mitigated with the allocation of one or more Navy Aegis ships to protect it, but those ships would be inhibited from performing other critical missions. Therefore, one of the purposes of the Defense of Guam is to free up Navy Aegis ships for those critical missions. The authors also believe that the Defense of Guam makes USAF power projection much more viable. However, it is unclear what the USAF future posture plans are at Andersen Air Force Base. Therefore, a Guam Master Plan is imperative. See Carl Rehberg and Josh Chang, *Moving Pieces*, 2022.

171 Jason Sherman, "Legislation would direct DOD to codify options for Aegis Ashore defense against Russia," *Inside Defense*, June 16, 2023, https://insidedefense.com/daily-news/legislation-would-direct-dod-codify-options-aegis-ashore-defense-against-russia. The article talks specifically of the need to physically harden Aegis Ashore sites in Europe.

172 RADM (ret) Mark Montgomery, Sept 1, 2022, p. 13. Also, RADM (ret) Mark Montgomery, May 17, 2023 & August 17, 2023.

173 RADM (ret) Mark Montgomery, May 17, 2023, p. 18.

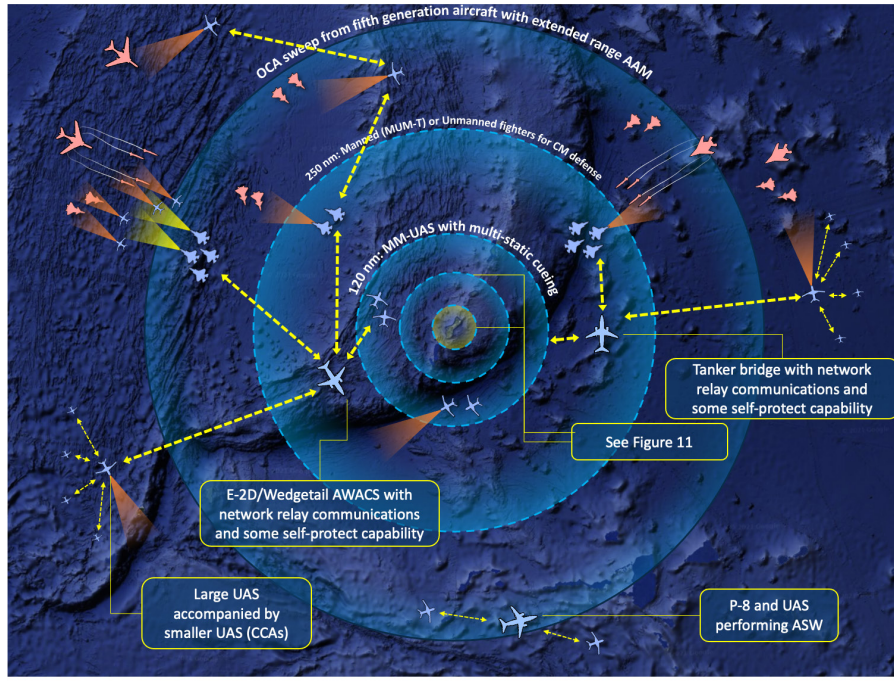
174 Congressional Research Service (CRS), "The U.S. Army's Strategic Mid-Range Fires (SMRF) System," updated July 6, 2023, https://crsreports.congress.gov/product/pdf/IF/IF12135.

175 RADM (ret) Mark Montgomery, "Taiwan and China: The Missile Defense Challenge" MDAA Webinar and Transcript, September 1, 2022, pp. 11-14.

176 Based on the FY2023 NDAA additional VLS launchers were added due to concerns with the SMRF timeline.

Exploring and Illustrating Ideas for Guam's Defense

FIGURE 9: ILLUSTRATION OF POTENTIAL GUAM "OUTER" SALVO DEFENSE RINGS

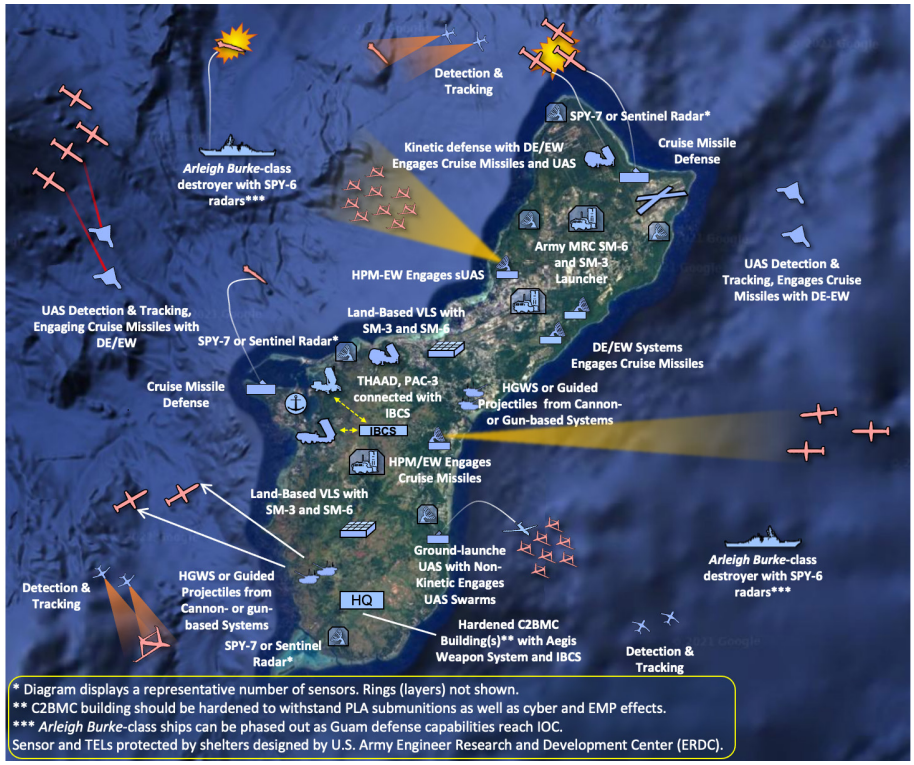


Source: Graphic created by CSBA. Adapted and updated from the original graphic in Mark Gunzinger, Carl Rehberg, et al., *An Air Force For an Era of Great Power Competition* (Washington, DC: Center for Strategic and Budgetary Assessments, 2019).

Figure 10 depicts some outer layers of a possible future of defense around Guam. One of the chief goals of these outer layers would be to protect against enemy bombers (and other aircraft), submarines, and ships – detecting and, if possible, eliminating them before they launch their payloads. This places a premium on creating dense, persistent, redundant, and resilient networks of undersea, surface, airborne, and space sensors.

Multi-mission UAS, including HALE UAS, could provide high-capacity, continuous, and all-aspect short- and medium-range sensing and defenses in the outer layers of defenses. The use of manned fighter aircraft and current UAS for DCA CAPs would address Defense of Guam capability timelines ASAP while providing additional layers of defense. In the near- to mid-term, manned-unmanned teaming (MUM-T) using large attritables or reusable UAS (including Collaborative Combat Aircraft—CCAs) could be added for a mix of capabilities that is more resilient and cost-effective.

FIGURE 10: ILLUSTRATION OF POTENTIAL GUAM "INNER" AND "CLOSE-IN" SALVO DEFENSE RINGS[177]



Source: Graphic created by CSBA.

A close-in layer of active defense must also be enhanced to meet emerging threats. Cruise missile defense systems like USMC's GBAD MRIC, NASAMS, HVP systems like the Hypervelocity Gun Weapons System (HGWS),[178] or other emerging cannon and gun-based systems could support this role.[179] These systems should be supplemented by non-kinetic capabilities such as high-powered microwave and electronic warfare (HPM/EW) systems.

Lastly, although centralized command and control is desirable, the system should also be capable of disaggregated operations if parts of the BMC2 network become disconnected.

177 The various types of systems, their numbers and location is representative for illustration only. The purpose is to show the concepts and the variety of technologies and systems that could provide solutions.

178 Joseph Trevithick, "Railgun Ammo-Firing Cannon Being Eyed By Air Force For Cruise Missile Defense (Updated)," *The War Zone*, May 1, 2022, https://www.thedrive.com/the-war-zone/counter-cruise-missile-cannon-firing-navy-railgun-ammo-being-eyed-by-air-force.

179 NSWCDD Corporate Communications, "Showing the Skills: NSWCDD-Led Capabilities Showcased in Twitter Video," Naval Sea Systems Command, February 11, 2021, https://www.navsea.navy.mil/Media/News/SavedNewsModule/Article/2501841/showing-the-skills-nswcdd-led-%20%20%20%20%20%20%20%20%20%20capabilities-showcased-in-twitter-video/. The are other options also, see Mike Gallagher, Chairman, Select Committee on the Chinese Communist Party, "Letter to The Honorable Christine Wormuth," November 13, 2023, https://selectcommitteeontheccp.house.gov/media/letters/letter-army-secretary-defense-guam-chinese-missiles.

When available, the E-7 Wedgetail and UAS with sensors would extend and augment the radar coverage and support directing fighter or UAS aircraft for intercepting incoming cruise missiles, aircraft that include UAS and sUAS swarms. Provisions should be made for integrating numerous sensors to operate as part of the overall architecture to provide CEC-like and IBCS capabilities. Multiple simulations in an Integrated Testbed (ITB) should be accomplished to refine the architecture over time and train personnel for enhanced operational readiness. Now more than ever, moving from proprietary systems toward a more open architecture that allows users (the United States and close allies) to plug and play with complementary and interdependent systems vital to effectiveness and economies of scale to mitigate costs.[180] The Army's IBCS has achieved initial operational capability and is ready to begin fielding of the system. IBCS "extends the battlespace by disaggregating sensors and effectors".[181]Although Navy CEC capabilities do not appear to be part of the Guam Defense System architecture, IBCS will become more interoperable with CEC since both are critical for future JADC2 capabilities [182]

Summary and a Way Forward for Guam's Defenses

The Defense of Guam remains critical due to its strategic importance as the hub for concentrating long-range strike efforts along the second island chain in the Indo-Pacific region. Guam is already vulnerable to complex attacks of large salvos of ballistic and cruise missiles and UAS. Efforts to develop layered, comprehensive, and distributed integrated air and missile defenses are crucial to U.S. military operations in the Indo-Pacific.

Several important reports have been released in recent months depicting more details of the Defense of Guam. Some now state that Guam could be the best-defended location in the U.S. However, based on the details released and the goals of the program, several critical issues need prompt attention:

The first is the timeline for improvements to Guam's defenses. Notably, the current timeline does not meet ADM Aquilino's or ADM (ret) Davidson's expectations—based on the latest GAO report from May 2023.[183] As one expert has noted, the Department of Defense appears to have "settled on the most expensive, least efficient and slowest delivered possible plan."[184]

180 Kenneth Todorov, "Missile Defense: Getting to the Elusive Right Side of the Cost Curve," Center for Strategic and International Studies, April 8, 2016, https://www.csis.org/analysis/missile-defense-getting-elusive-right-side-cost-curve.

181 Northrop Grumman, "Northrop Grumman's Integrated Battle Command System Achieves Initial Operational Capability", May 1, 2023, https://news.northropgrumman.com/news/releases/northrop-grummans-integrated-battle-command-system-achieves-initial-operational-capability

182 MDA, "MDA Tech Bridges Gap Between Disparate Sensors, Fire Control Systems" July 21, 2023, https://www.mda.mil/news/21news0011.html.

183 Government Accountability Office (GAO), *Missile Defense: Annual Goals Unmet for Deliveries and Testing* (Washington, DC: Government Accountability Office, May 2023),

184 RADM (ret) Mark Montgomery, Transcript-MDAA Virtual Event: "The Missile Defense 'Must Do' List for the FY-24 NDAA," May 17, 2023, p. 14,

The second is the impact of delays in the development of key IAMD capabilities. Key systems are still in doubt—especially when it comes to cruise missile defense. The current plan is likely very dependent on the Army's IFPC 2-I close-in cruise missile defense.[185] Nevertheless, there is a need for layers of sensors and effectors with different ranges, which could likely be best achieved with manned and unmanned airborne platforms. In addition, persistent elevated sensors appear to be missing in the plan and a needed timeline for robust hypersonic missile defense.[186]

The third is the apparent lack of attention to personnel and infrastructure requirements.[187] Indeed, the non-material (i.e., DOTMILPF) implications of Guam's future defense may be the Achilles heel of current plans because significant personnel will be needed to operate these systems. These personnel will impact both costs and timelines. [188] Notably, INDOPACOM has estimated that the costs to develop and deploy the Defense of Guam will reach $4.4B.[189] Yet this estimate did not appear to include DOTMLPF costs beyond initial capabilities. More cost-effective solutions need exploration. There is a need for innovation and out-of-box thinking. For instance, the Department should consider using Guam Army National Guard (ARNG) and USMC personnel, namely by converting some existing personnel or units to air defense artillery units. Most ARNG personnel are already located at Guam/CNMI, and many USMC personnel are scheduled to arrive in the next few years. These personnel would not need the same infrastructure as bringing new active-duty Army personnel from outside of Guam. In addition, with IFPC 2-I delayed, the use of USMC GBAD MRIC (for cruise missile defense) could help to shrink timelines and contain costs—especially if some USMC personnel currently associated with DPRI and Camp Blaz are converted to defending Guam. Other options should be considered. For example, the planned movement of a detachment of Republic of Singapore Air Force (RSAF) fighters to AAFB (by 2029) should be evaluated in light of the importance of the Guam Defense System.[190] In a recent CRS report, the Air Force Office of Legislative Affairs expressed concern that AAFB is "not

185 Ibid., Table 9, p. 40. The GAO report shows a PAC-3 launcher in the mix but there are no details of how PAC-3s would be used. PAC-3s are generally not cost-effective for CMD due system and interceptor costs.

186 There were some concerns regarding the USA's Mid-Range Capability (MRC) system in the last year, but these concerns have been mitigated. RADM (ret) Mark Montgomery, Transcript-MDAA Virtual Event: "Missile Defense of Guam: No Time To Waste—No Time To Lose," August 17, 2023, p. x, https://missiledefenseadvocacy.org/wp-content/uploads/2023/08/MDAA-Virtual-Event-Transcript-Missile-Defense-of-Guam-No-Time-to-Waste-No-Time-to-Lose-.pdf.

187 RADM (ret) Mark Montgomery, August 17, 2023, pp. 14-15. However, on June 20, 2023, DSD Hicks designated the Army the lead service for the Defense of Guam and requested a series of reports to include one with a complete evaluation of the DOTMILPF implications. Jason Sherman, "Army readying key recommendations on Defense of Guam for DOD leaders, " *Inside Defense*, August 22, 2023, https://insidedefense.com/daily-news/army-readying-key-recommendations-defense-guam-dod-leaders.

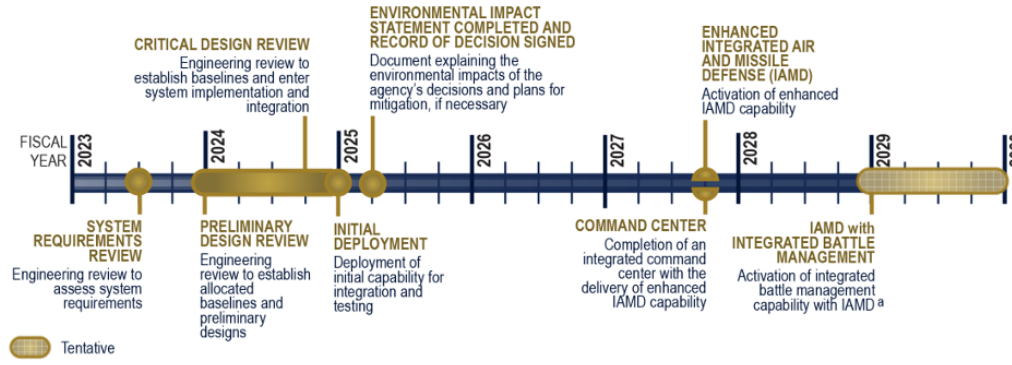
188 RADM (ret) Mark Montgomery, August 17, 2023, pp. 14-15.

189 Jason Sherman, "Legislation proposes top acquisition status for new Guam missile defense system," *Inside Defense*, July 19, 2022, https://insidedefense.com/daily-news/legislation-proposes-top-acquisition-status-new-guam-missile-defense-system.

190 Rehberg and Chang. *Moving Pieces*, pp. 27-29. See also CRS, "Guam Defense Infrastructure and Readiness," CRS R47643, August 3, 2023, p. 3, https://crsreports.congress.gov/product/pdf/R/R47643.

equipped with the material and personnel necessary to be an effective hub."[191] With the national priority on the Guam Defense System, there appears to be a significant disconnect with Air Force priorities for AAFB.

FIGURE 11: GUAM DEFENSE SYSTEM KEY MILESTONES AND EVENTS



Source: GAO analysis of Missile Defense Agency data. | GAO-23-106011

[a]This event is not yet baselined and will not occur before the first quarter of fiscal year 2029.

Source: GAO

191 CRS, "Guam Defense Infrastructure and Readiness," August 3, 2023, p. 15.

CHAPTER 4

Conclusion and Recommendations

Developing high-capacity and cost-effective active defenses to protect America's forward bases against guided weapon salvos will be vital to deterring great power aggression and other threats to the security and stability of the Indo-Pacific region. Without these defenses, the U.S. military may be unable to quickly counter other A2/AD threats and project offensive power in future operations. Growing threats necessitate options to prevent surprise attacks, pre-emption, and a *fait accompli*. Those options, in turn, will require new concepts, technologies, roles, and missions.

The concepts and capabilities discussed in the report constitute several possible paths toward developing layered, comprehensive, and distributed defenses with novel non-kinetic and kinetic systems to defeat salvo attacks. The combination of UAS, directed energy weapons, and lower-cost kinetic weapons could dramatically increase the difficulties adversaries would face should they attempt to attack the United States, its allies, and its partners.

Recommendations for Future Regional Salvo Defenses

DoD and Congress should support the development of operating concepts and a new generation of cost-effective active and passive defenses and attack operations capabilities that could help protect the U.S. military's forward bases, ports, and pre-positioned sites against salvo attacks and complex salvo attacks. As recommended by previous CSBA assessments, the first step toward achieving this objective is to frame the challenge as a salvo competition between adversaries that can conduct attacks with hundreds and possibly thousands of guided weapons instead of just a small number of ballistic missiles.[192]

192 Jason Sherman, "MDA tasked to explore missile defense policy shift, brace for 'regional' strikes by Russia, China," *Inside Defense*, August 28, 2023, https://insidedefense.com/daily-news/mda-tasked-explore-missile-defense-policy-shift-brace-regional-strikes-russia-china.

In addition, the Department of Defense and others should consider the following recommendations:

Continue fully supporting USINDOPACOM's #1 PDI goal—the Guam Defense System. DoD, USINDOPACOM, and Congress should continue to support the Guam Defense System. However, the DoD and Congress must demand urgency for a timely implementable plan with needed capability, cost-effectiveness, minimal personnel, and infrastructure. Basic initial operating capabilities (for some threats) are on track for 2025. However, many planned capabilities for the Guam Defense System are likely not executable, too costly, and well past required or needed timelines. One of the biggest impediments appears to be non-material (i.e., DOTMLPF-P). Congress should immediately hold hearings to discover the problems' root cause(s) and take corrective actions as soon as possible. In addition, creative and innovative options must be developed for the Defense of Guam that account for DOTMLPF-P aspects—especially the personnel and facilities needed to operate and sustain. Finally, a new Guam Master Plan must de-conflict with the other priority projects for Guam and possibly some Guam projects that should defer to the Guam Defense System.[193]

Continue CEC and IBCS integration to support battle management command and control (BMC2) and leverage new JADC2 efforts. DoD should develop JADC2 capabilities that consist of advanced tactical C2 capabilities leveraging existing DoD investments and fielded capability across the services.

Field UAS with sensors to perform persistent detection/early warning of salvo attacks. Sensors (active electronically scanned arrays, infrared, and others) could be integrated into current generation and future UASs (including HALE UAS) to help detect and provide early warning of missile salvos and associated "track" information. Integrated with other space, ground, and sea-based sensors, CAPs of long endurance ISR UAS and HALE UAS could help fill DoD's existing gap in capabilities to detect salvos of land-attack cruise missiles, armed UAS, and other emerging threats.

Field lower-cost, short- to medium-range kinetic and non-kinetic sUAS defenses. A mix of low-cost kinetic and non-kinetic interceptors could provide cost-effective solutions for sUAS/sUAS swarm threats. The JCO, working with the Air Force and DoD, should place these capabilities on UAS to extend range, which would provide a layered defense while making it layered, comprehensive, and distributed. DoD should continue to request funding to develop, test, and, if feasible, procure gun systems that would provide a high-capacity, lower-cost kinetic defense against multiple classes of air and missile threats.

Prototype UAS with HELs & HPM/EW. DoD should quickly integrate 150+ kW-class lasers in fighter-size UAS and a 300 kW-class laser on a larger UAS. Current UAS have sufficient payload, power generation capacity, and other performance characteristics (i.e., SWaP)

193 CRS, "Guam Defense Infrastructure and Readiness," CRS R47643, August 3, 2023, https://crsreports.congress.gov/product/pdf/R/R47643.

needed to support the integration of HELs. In addition, HPM/EW capabilities should be adapted, integrated, and tested with several classes of UAS (e.g., air-launched versions of non-kinetic capabilities).

Acquire multiple types of HPM/EW defenses. DoD should take advantage of nascent HPM technologies demonstrated by the THOR C-UAS program and its follow-on programs (e.g., Mjolnir). In addition, DoD should procure higher power and longer-range HPM/EW systems that are capable against UAS swarms, cruise missiles, and other threats. HPM/EW systems have started to demonstrate true "salvo defense" capability since they can quickly degrade or defeat multiple weapons per salvo.

Develop Alternatives for IFPC 2-I for INDOPACOM—Cost-Effective & Timely Cruise Missile Defense (CMD). To fill capability gaps due to delays in IFPC 2-I, other options should be considered, including the USMC's GBAD MRIC, as well as gun systems (e.g., HGWS), and other options. The MRIC system and associated Tamir missile (and gun systems) represent a significant reduction in cost per missile fired over established programs of record that bend the cost curve of active defenses.

Responsibilities for IAMD defense inside and outside DoD must improve for effectiveness. DoD, working with Congress and others, must continue to work out the seams associated with the labyrinth of organizations that are often less than optimum in the rapidly changing IAMD world. The Army and Air Force appear to have made some progress with Section 156 of the FY2021 NDAA as a forcing function. However, a public statement and release of the report is warranted. This nascent strategy should have a follow-up MOU with an accountability mechanism(s) that resides with the combatant commander—INDOPACOM.

Enhanced IAMD Integrated Test Bed for USINDOPACOM. Best practices for development, innovation, test, and training include the use of an ITB that is separate from the operational system but that is sufficiently robust and sophisticated that it can emulate the operational architecture, conditions, and threats, and, by doing so, provide for realistic training (including TTPs), experimentation, and IAMD development.

LIST OF ACRONYMS

A2/AD	anti-access and area-denial
AAD	Advanced Air Defense
AAM	air-to-air missile
AAW	anti-air warfare
AB	Airbase
ACE	Agile Combat Employment
ADC	Air Defense Command
ADIZ	Air Defense Identification Zone
AESA	active electronically scanned array
AF	Air Force
AFB	Air Force Base
AFRL	Air Force Research Labs
AGM	air-to-ground munition
ALCM	air-launched cruise missile
ALTBMD	Active Layered Theatre Ballistic Missile Defense
AMD	air and missile defense
APOD	aerial port of debarkation
ARNG	Army National Guard
ASW	anti-submarine warfare
AWACS	airborne warning and control system
BMC2	battle management command and control
BMC3	battle management, command, control, and communications
BMDS	Ballistic Missile Defense System
BVR	beyond visual range
C3ISR	command, control, communications, intelligence, surveillance, and reconnaissance
CCA	collaborative combat aircraft
CEC	Cooperative Engagement Capability
CENTCOM	Central Command
CHAMP	Counter-electronics High-powered Microwave Advanced Missile Project
CM	cruise missile
CMD	cruise missile defense
COFA	Compact of Free Association
COIL	chemical oxygen iodine laser
CONOP	concept of operations

C-RAM	counter rocket, artillery, and mortar
CSBA	Center for Strategic and Budgetary Assessments
CSG	Carrier Strike Group
DARPA	Defense Advanced Research Projects Agency
DCA	defensive counter-air
DIA	Defense Intelligence Agency
DMO	Distributed Maritime Operations
DOD	Department of Defense
DoDD	Department of Defense Directive
DOTMLPF-P	Doctrine, Organization, Training, Material, Logistics, Personnel, Facilities and Policy
DSCA	Defense Security Cooperation Agency
EABO	Expeditionary Advanced Base Operations
EADTB	Extended Air Defense Testbed
EAMDEX	European Air and Missile Defense Exercise
ECS	East China Sea
EIAMDC	European Integrated Air and Missile Defense Center
EISS	Enhanced Integrated Sensor Suites
EMD	Eastern Military District
EMP	electromagnetic pulse
ETB	European Test Bed
EO	electro-optical
EOTS	electro-optical targeting system
ER	extended range
EUCOM	European Command
FAS	Freely Associated States
FMS	foreign military sale
FY	fiscal year
FYDP	future year defense program
GBAD	Ground-Based Air Defense
GBI	Ground Based Interceptors
GLONASS	Global Navigation Satellite System
GLCM	ground-launched cruise missile
GMD	Ground-Based Midcourse Defense
GOJ	Government of Japan
GPI	Glide Phase Interceptor
GPS	Global Positioning System

G-RAMM	guided-rockets, artillery, missiles, and mortars
HALE	high-altitude long endurance
HEL	high energy laser
HELIOS	High Energy Laser and Integrated Optical-dazzler with Surveillance
HELLADS	High Energy Liquid Laser Area Defense System
HELSI	High Energy Laser Scaling Initiative
HGV	hypersonic glide vehicle
HPM	high power microwave
HVP	hyper-velocity projectile
IADS	integrated air defense systems
IAF	Israeli Air Force
IAMD	integrated air and missile defense
ISAMD	Integrated Space, Air and Missile Defense
IBCS	Integrated Air and Missile Defense Battle Command System
ICBM	intercontinental ballistic missile
IFF	identification, friend or foe
IFPC	Indirect Fire Protection Capability
INDOPACOM	Indo-Pacific Command
INF Treaty	Intermediate-Range Nuclear Forces Treaty
IPD	intelligence preparation of the battlespace
IR	Infrared
IRBM	intermediate-range ballistic missiles
ISR	intelligence, surveillance, and reconnaissance
ITB	integrated test bed
JADGE	Japan Air Defense Ground Environment
JASSM	Joint Air-to-Surface Standoff Missile
JASSM-ER	Joint Air-to-Surface Standoff Missile Extended Range
JCO	Joint C-sUAS Office
JBTEC	Joint Ballistic Missile Defense Training & Education Center
JGSDF	Japan Ground Self-Defense Force
JHPSSL	Joint High-Power Solid-State Laser
JMSDF	Japan Maritime Self-Defense Force
JSDF	Japanese Self-Defense Force
JSM	Joint Strike Missile
Km	Kilometer
Kw	Kilowatt

LACM	land-attack cruise missile
LOC	line of communication
LPWS	Land-based Phalanx Weapon System
LRASM	Long-Range Anti-Ship Missile
MDA	Missile Defense Agency
MDIOC	Missile Defense Integration and Operations Center
MML	Multi-Mission Launcher
MOD	Ministry of Defense
MRBM	medium-range ballistic missiles
MRIC	Medium Range Intercept Capability
MSE	Missile Segment Enhancement
MTI	moving target indicator
NASAMS	National Advanced Surface-to-Air Missile System
NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NGI	Next-Generation Interceptor
NIFC-CA	Naval Integrated Fire Control-Counter Air
NKAF	North Korean Air Force
Nm	nautical mile
OCA	offensive counter-air
OCONUS	outside continental United States
OODA	Observe, Orient, Decide, Act
OPCON	operational control
OPIR	Overhead Persistent Infrared
OSD	Office of the Secretary of Defense
OTH	over-the-horizon
PAC	Patriot Advance Capability
PDI	Pacific Deterrence Initiative
PGM	precision-guided munition
PGW	precision-guided weapon
P_k	probability of kill
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
PLARF	People's Liberation Army Rocket Forces
POL	petroleum, oils, and lubricants

RAAF	Royal Australian Air Force
RELI	Robust Electric Laser Initiative
RHEL	Ruggedized High Energy Laser
ROK	Republic of Korea
SAM	surface-to-air missile
SAR	synthetic aperture radar
SHORAD	short-range air defense
SLBM	submarine-launched ballistic missile
SLOC	sea line of communication
SPOD	seaport of debarkation
SRBM	short-range ballistic missiles
SSL	solid-state lasers
STOVL	short take-off and vertical landing
sUAS	small unmanned aerial system
TBM	theater ballistic missile
THAAD	Terminal High Altitude Air Defense
THOR	Tactical-Power Operational Responder
TTP	tactics, techniques, and procedures
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
USA	U.S. Army
USAF	U.S. Air Force
USFJ	U.S. Forces Japan
USMC	U.S. Marine Corps

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