Department of the Air Force

# ASOR

## Air & Space Operations Review

Strategic Missile Defense

Disinformation and Entropy

An Integrated Space Test Lexicon

From Cars to People

Combat Casualty Care

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Department of the Air Force

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## Air & Space Operations Review

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# Air & Space Operations Review

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## BOOK REVIEWS

## FROM THE EDITOR

Dear Reader,

From the conundrum of national ballistic missile defense to the structure of combat casualty care in a major power war, the summer issue of *Air & Space Operations Review* (*ASOR*) considers a wide range of topics important to the many elements of global military operations.

In our lead article, Stephen Cimbala and Adam Lowther explore the technology of missile defenses to provide analytical benchmarks for these defense systems and their relationship to arms control, deterrence, and policy. We then turn to José Davis and his examination of the Air Force's growing understanding of the information environment in our age of artificial intelligence, and his recommended strategies for successful operations.

Transitioning to space operations and the critical element of research, development, and testing, Stephen Tullino, Andrew Keys, Robert Bettinger, Amy Cox, and David Jacques offer an integrated space test lexicon intended to unite the myriad definitions of integrated test, developmental test, and operational test across the Department of Defense to better execute those essential processes in support of critical space systems operations.

In our fourth article, Louis Zib and Christopher Chini find that Air Force installations could be more resilient to contemporary threats by updating base design to focus on people rather than cars, a design that follows the mid-twentieth-century car-centric model common to Air Force installations today. Our issue's final offering is an analysis of the combatant command trauma system. Mason Remondelli, Ryan Leone, Collin Todd, Natalia Barzanji, Jennifer Gurney, Teresa Duquette-Frame, Jason Brill, and Derek Licina find that the potential for a theater war in the Indo-Pacific region demands the transformation of the existing combatant command trauma system into a DoD-supported global trauma system intended to reinforce casualty care in such a conflict.

Our issue concludes with a selection of our latest book reviews, all of which can be found at our website. Thank you for your continued interest in the journal. On behalf of Team *ASOR*, enjoy what remains of summer 2024, and continue to champion the importance of civility, mutual respect, and care for one another.

~ The Editor

# Strategic Missile Defense and Nuclear Arms Control

## Aspirations and Achievable Goals

Stephen J. Cimbala
Adam Lowther

This article considers the context of the current technology and policy climate to determine the favorability of a nationwide missile defense system that would protect the United States against a large-scale attack from a major power such as Russia or China. By studying the technology, including pertinent discussions of missile defenses and their relation to Russian and American security policy, this article establishes some analytical benchmarks for missile defenses and their probable impacts on nuclear deterrence, arms control, and politics. In short, missile defenses have utility, but they are not a panacea for defending the nation against ballistic missile attack.

The role of missile defenses in American national security policy and arms control remains a contentious issue more than six decades since they were first seriously contemplated. Cold War experience suggested that a ballistic missile attack would inevitably overwhelm any nationwide ballistic missile defenses (BMD) but could be useful in the event of a limited attack.[1] Such missile defenses could raise the number of intercontinental ballistic missiles (ICBMs) needed to destroy an adversary's ICBM force.[2] Thus, they were useful, but only in certain circumstances.

Since the 1980s, significant research and development funding sought to improve missile defense technologies within the constraints of the Anti-Ballistic Missile Treaty, the 1972 arms control treaty between the United States and the Soviet Union that limited antiballistic missile systems to a small number of systems in a designated area. The United States largely abandoned ballistic missile defenses, while the Soviets primarily focused on nuclear-tipped missiles defending Moscow.[3] Deployable ballistic missile defenses against

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1. Stephen Hildreth, *Ballistic Missile Defense: Historical Overview*, RS 22120 (Washington, DC: Congressional Research Service [CRS], 2008), 2, https://crsreports.congress.gov/.

2. Adam Lowther and Derek Williams, "Why America Has a Launch under Attack Option," *War on the Rocks*, July 10, 2023, https://warontherocks.com/.

3. Jeff Sessions, "Ballistic Missile Defense: A National Priority," *Strategic Studies Quarterly* 2, no. 2 (2008); and see also David Yost, *Soviet Ballistic Missile Defense and the Western Alliance* (Cambridge, MA: Harvard University Press, 1988).

threats of short-, medium-, and intermediate-ranges made considerable strides since the Cold War ended. But the greater challenge remains in developing and deploying an effective nationwide system that protects the population against large-scale attacks by major powers such as Russia or China.[4]

Will the emerging strategic environment over the next decade or more prove more favorable to the development of preclusive defenses against large-scale attacks? Forecasts are uncertain, but the Strategic Posture Commission's final report offers sound insight into what future threats may look like.[5] Based on the congressional commission's analysis and that of the authors, it appears several broad factors will play an important role in the future.

First, the United States is entering an era of advanced precision strike regimes. More kinds of long-range attacks, with improved accuracies for conventional or nuclear weapons, are now possible against point or area targets.[6] The number and variety of such attacks will only increase over time. Second, the significance of the space and cyber domains for all levels of warfare is becoming more apparent to major powers, other states, and even nonstate actors.[7] The importance of space in early warning, surveillance, and reconnaissance, and potentially strike, is growing.

Third, the digitization of knowledge and experience, together with the globalization of communications and commerce, produced the MOM factor—the preeminence of mind over matter. This context places at the center of military-strategic planning and thinking the need for mastery of the human-machine interface.

For example, the growing significance of artificial intelligence (AI) radiates outward into broader effects on the ability of the United States to master control of the observe, orient, decide, and act loop (OODA) compared to its competitors.[8] How much decision making of what kind can be delegated to machine learning is the great debate among corporate, political, and military leaders today and for the next several decades.[9] As the

4. See Michaela Dodge, *Missile Defense Reckoning Is Coming: Will the United States Choose to Be Vulnerable to All Long-Range Missiles*? (Fairfax, VA: National Institute for Public Policy, 2020); and see also Andrew Futter, *Ballistic Missile Defense and US National Security Policy: Normalization and Acceptance after the Cold War* (New York: Routledge, 2013).

5. Madelyn Creedon and John Kyl, *America's Strategic Posture* (Washington, DC: Institute for Defense Analysis, 2023), https://armedservices.house.gov/.

6. See Amy Wolf, *Conventional Prompt Global Strike and Long-Range Ballistic Missiles: Background and Issues* (Washington, DC: CRS, 2021); and Thomas Newdick, "Takeaways from Russia's Missile War on Ukraine," *War Zone*, November 14, 2023, https://www.twz.com/.

7. For example, see Brian Weeden and Victoria Samson, eds., *Global Counterspace Capabilities: An Open-Source Assessment* (Washington, DC: Secure World Foundation, 2023); and David E. Sanger, *The Perfect Weapon: War, Sabotage, and Fear in the Cyber Age* (New York: Crown Publishing, 2018).

8. John Boyd, "The Essence of Winning and Losing," slide presentation, 1995, https://coljohnboyd.com/.

9. George Galdorissi and Sam Tangredi, "Algorithms of Armageddon: What Happens When We Insert AI into Our Military Weapons Systems?" (presentation, Department of Defense [DoD] Strategic Multilayer Assessment, April 27, 2021).

Strategic Posture Commission emphasizes, Russia and China are seeking to master these areas. In some instances they are well ahead of the United States.

Does the preceding context open the door to a technology and policy climate more favorable to the emergence of strategic missile defenses? This article considers the political setting for Russian and American missile defense and related issues of nuclear arms control and deterrence. In studying the technology, including pertinent discussions of missile defenses and their relation to Russian and American security policy, this article establishes some analytical benchmarks for missile defenses and their probable impacts, if any, on Russo-American nuclear deterrence, arms control, and politics.

## The Political Setting

Russia and the United States began drifting into separate orbits on issues related to nuclear arms control soon after the 2010 conclusion of the New Strategic Arms Reduction Treaty (New START). Russia's annexation of Crimea (2014) and its invasion of Ukraine (2022) put further consideration of nuclear arms control on hold during the first two years of the Biden presidency—even as the administration attempted to coax Russia to remain a partner.[10] Russia's announced suspension of New START in spring 2023 and disinterest in any follow-on agreement added to the impasse on security issues between Moscow and Washington. Even if a settlement of Russia's war in Ukraine is reached before New START's expiration in 2026, a restart of the arms control process would involve a number of thorny issues.[11]

Included among the bones of contention is the question of American ballistic missile defenses, including homeland missile defenses and US contributions to NATO's European Phased Adaptive Approach for missile defenses in Europe designed to protect it against short-, medium-, and intermediate-range ballistic missiles launched from Iran.[12] At every opportunity, Russian President Vladimir Putin and other high-ranking Russian officials raise objections to American plans for deploying components of missile defense systems

10. Nicholas Gvosdev, "The Confrontation with Russia and US Grand Strategy," Foreign Policy Research Institute, February 16, 2023, https://www.fpri.org/; and Hanna Notte, "US Russian Relations Can Still Get Worse," *War on the Rocks*, February 22, 2023, https://warontherocks.com/.

11. Steven Pifer, "The US and Russia Must Re-assess Their Strategic Relations in a World without New START," *Bulletin of the Atomic Scientists*, June 13, 2023, https://thebulletin.org/; see also Stephen J. Cimbala and Adam Lowther, "The Future of Strategic Nuclear Arms Control," *Perspectives: Aether-ASOR*, March 1, 2023, https://www.airuniversity.af.edu/; and Stephen J. Cimbala and Lawrence J. Korb, "Reviving Arms Control, Post-Ukraine: Why New START Still Matters," *Bulletin of the Atomic Scientists*, July 13, 2022, https://thebulletin.org/.

12. Karen Kaya, "NATO Missile Defense and the View from the Front Line," *Joint Forces Quarterly* 71, no. 4 (2013); also see Steven J. Whitmore and John R. Deni, *NATO Missile Defense and the European Phased Adaptive Approach: The Implications of Burden Sharing and the Underappreciated Role of the U.S. Army* (Carlisle, PA: Strategic Studies Institute, 2013); Patrick J. O'Reilly, "Ballistic Missile Defense Overview" (presentation, 10th Annual Missile Defense Conference, Washington, DC, March 26, 2012); and *NATO Ballistic Missile Defense (BMD) Fact Sheet* (Brussels: NATO, 2012), https://www.nato.int/.

ashore and afloat in Europe.[13] Russian political and military leaders indicate that they may hold hostage other nuclear arms control agreements and engage in offensive countermeasures to thwart any American defenses.[14]

Prior to its war against Ukraine, Russia expected to modernize its strategic nuclear forces within the constraints of New START. The treaty required the United States and Russia to reduce their numbers of operationally deployed strategic nuclear warheads—including ICBMs, submarine launched ballistic missiles, and heavy bombers—to 1,550 on no more than 700 delivery vehicles by the end of 2018.[15] Additionally, the treaty provided for inspections and verification measures to ensure compliance. New START, however, began to fall apart long before the invasion of Ukraine. Even before the beginning of the coronavirus pandemic, Russia ceased its participation in onsite inspections, which were a key verification requirement in the treaty.[16]

Nuclear arms control is one important tool for American and Russian leaders, but it is not a substitute for coherent foreign policy, nor for well-thought-out military strategy. States do not fight because they have arms, but because they have political disputes that they are either unable or unwilling to resolve by means short of war. As instruments of warfighting, nuclear weapons offer a poor menu of options. The deterrent value of nuclear weapons lies in their capacity to destroy targets that adversaries value, even as nations think about how to limit collateral damage from an adversary's use of nuclear weapons against the homeland.

Deterrence is a psychological transaction between states in a competitive, and probably adversarial, relationship. How can one know that a prospective opponent is truly "deterred" from one or another course of action? The absence of an undesired behavior does not demonstrate the success or failure of deterrence, because other reasons may cause the prospective attacker to hesitate. Causation in matters of international politics, especially war and peace, is complex and includes a mix of objective and subjective factors. Even after the fact, historians argue about the causes of major wars. Politicians coping with the same decisions in real time are even more challenged to get it right.

Nuclear weapons grew up with the Cold War and with the adjustment of the Americans and Soviets to the idea of mutual deterrence and its military support. The Cold War superpowers and their militaries had time to adjust to the idea that the threat of nuclear war could be a necessary means to the avoidance of nuclear war or conventional war with a significant possibility of escalation into nuclear first use.

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13. Jack Detsch, "Putin's Fixation with an Old-School U. S. Missile Launcher," FP [*Foreign Policy*], January 12, 2022, https://foreignpolicy.com/.

14. Detsch; and see also "Ballistic Missile Defence," NATO, last updated July 26, 2023, https://www.nato.int/.

15. Treaty between the United States of America and the Russian Federation on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, April 8, 2010, Treaty Document 111-5, https://www.state.gov/.

16. Mike Eckel, "How Bad Are Things between Russia and the US? They Can't Even Agree to Discuss Nuclear Weapons Inspections," RadioFreeEurope, December 2, 2022, https://www.rferl.org/.

The post-Cold War environment is unlikely to proceed at such a leisurely pace as did the first nuclear age.[17] Instead, new nuclear forces in Asia and elsewhere are chasing a clock of nuclear multipolarity.[18] Already nuclear armed states in Asia include Russia, China, India, Pakistan, and North Korea. Japan and South Korea are the two most likely nations to go nuclear in the years ahead.[19]

Decisions by Washington and Moscow about their bilateral nuclear deterrence relationship are also related to the issue of nuclear proliferation—in Asia and elsewhere. China's nuclear modernization has immediate implications for Russia, India, Japan, South Korea, Taiwan, and the United States.[20] Should Iran choose the nuclear option, it will possess the capability to threaten not only Israel and the broader Middle East, but also much of Europe. An Iranian decision to go nuclear could very well set off a nuclear proliferation cascade with Saudi Arabia, Turkey, and Egypt purchasing the "Sunni bomb" from Pakistan.[21] North Korean nuclear weapons raise issues with respect to future Chinese, Japanese, Russian, American, and South Korean foreign policy.

The ability of the Americans and Russians to impose Cold War-style proliferation discipline over aspiring nuclear powers is a historical artifact that the United States is currently testing in South Korea and Japan. A Sino-American conflict over Taiwan would likely call the validity of the Washington Declaration—the mutual defense commitment made by Biden and South Korean President Yoon Suk Yeol in 2023 that allows for joint planning in response to North Korean nuclear employment—into question and potentially spark proliferation by both South Korea and Japan.[22] Such an act would undermine the credibility of American extended deterrence in Asia and, possibly, Europe.

17. See David A. Cooper, *Arms Control for the Third Nuclear Age: Between Disarmament and Armageddon* (Washington, DC: Georgetown University Press, 2021); Keith B. Payne and David J. Trachtenberg, *Deterrence in the Emerging Threat Environment: What is Different and Why it Matters* (Fairfax, VA: National Institute for Public Policy, 2022); Paul Bracken, *The Second Nuclear Age: Strategy, Danger, and the New Power Politics* (New York: Henry Holt, 2012); and Michael Krepon, *Better Safe Than Sorry: The Ironies of Living with the Bomb* (Stanford: Stanford University Press, 2009).

18. Christopher Preble, Zach Cooper, and Melanie Marlowe, "The Risk of Nuclear Proliferation in Asia," *War on the Rocks*, December 22, 2022, https://warontherocks.com/.

19. Stephen Cimbala, *The United States, Russia, and Nuclear Peace* (New York: Palgrave-McMillan, 2020).

20. See Center for Global Security Research Study Group, *China's Emergence as a Second Nuclear Peer: Implications for US Nuclear Deterrence Strategy* (Livermore, CA: Lawrence Livermore National Laboratory, 2023).

21. Hamza Mjahed, "The Nuclearization of the Middle East," *Policy Center for the New South, Policy Brief 20-76* (September 2020), http://large.stanford.edu/; and Aderito Vicente, "The Imminent Risk of Nuclear Proliferation in the Middle East," *EUIdeas*, November 12, 2019, https://euideas.eui.eu/.

22. Ankit Panda, "The Washington Declaration Is a Software Upgrade for the US-South Korea Alliance," Carnegie Endowment for International Peace, May 1, 2023, https://carnegieendowment.org/.

## Missile Defenses Then and Now

Missile defenses were controversial almost from the dawn of the nuclear age and remain so.[23] Nuclear weapons and long-range ballistic missiles seemed to overturn the historical dictum that, for every offense, there is a defense. Despite the research and development efforts of American and Soviet/Russian scientists throughout the Cold War and afterward, neither state was able to deploy nationwide missile defenses competitive with the speed and destructiveness of offenses.[24]

Part of the problem is that the technical task of missile defenses is much harder than that assigned to offenses.[25] Unless they were based on very advanced principles and/or partly based in space, missile defenses had to "hit a bullet with a bullet" during one of the four phases of the trajectory of a ballistic missile in flight. Interception had to take place within approximately 20 minutes of launch. Attack characterization and response require strategic and tactical indications and warning, reconnaissance, surveillance, and command and control systems that must perform flawlessly.

Because of the destructiveness of nuclear weapons, the attacker needs to penetrate the defenses with only a small percentage of their first-strike weapons. The defender, in contrast, must achieve perfect or nearly perfect intercept and destruction of attacking warheads. Otherwise, even if retaliatory forces were saved from destruction, collateral damage to populations is potentially enormous. The problem of indications and warnings provides one example of the difficulty of challenges facing prospective ballistic missile defense systems.[26]

New information and electronics technologies may bring new hope to proponents of missile defenses. Regarding the challenge posed by hypersonic weapons, for example, the US Missile Defense Agency (MDA) is integrating tracking capabilities among existing ground-based, sea-based, and space-based radars.[27] Aegis ships are now able to engage some hypersonic threats in the terminal phase of the attacking missile's flight path.[28] The

23. Graham Spinardi, "Technical Controversy and Ballistic Missile Defence: Disputing Epistemic Authority in the Development of Hit-to-Kill Technology," *Science as Culture* 23, no. 1 (2014), https://doi.org/.

24. See Rebecca Slayton, *Arguments That Count: Physics, Computing, and Missile Defense, 1949–2012* (Cambridge, MA: MIT Press, 2013); Donald R. Baucom, *The Origins of SDI, 1944–1983* (Lawrence: University Press of Kansas, 1992); Frances FitzGerald, *Way Out There in the Blue: Reagan, Star Wars and the End of the Cold War* (New York: Simon and Schuster, 2000); and Jennifer G. Mathers, *The Russian Nuclear Shield from Stalin to Yeltsin* (New York: St. Martin's Press, 2000).

25. Steven Hildreth et al., *Missile Defense: The Current Debate*, RL 31111 (Washington, DC: CRS, 2005).

26. Thomas K. Hensley et al., "Understanding the Indications and Warning Efforts of US Ballistic Missile Defense," *Joint Force Quarterly* 78, no. 3 (2015).

27. See Stephen J. Cimbala and Adam B. Lowther, "Hypersonic Weapons and Nuclear Deterrence," *Comparative Strategy* 41, no. 3 (2022); and Stephen Reny, "Nuclear-Armed Hypersonic Weapons and Nuclear Deterrence," *Strategic Studies Quarterly* 10, no. 4 (2020).

28. Abraham Mahshie, "Hypersonics Defense," *Air & Space Forces Magazine*, January 19, 2022, https://www.airandspaceforces.com/.

agency is working with the Navy to upgrade sea-based terminal defenses against more advanced hypersonic and maneuvering threats.

The MDA and the US Space Force are also working together to develop hypersonic ballistic tracking from space.[29] According to Navy Vice Admiral Jon A. Hill, former director of MDA, due to the global maneuver capabilities of hypersonic missiles, "A space-based tracking and targeting capability is in clear need."[30] With regard to ground-based missile defenses, the United States began deploying missile defenses in Alaska and California during the first term of President George W. Bush. It would not be too surprising if the near future sees dramatic technological breakthroughs in these and other missile defenses.

In recognition of the possibility that missile defenses may improve, offenses are unlikely to stand still. The standard scenario of Russo-American nuclear missile attack, with multiple firings of land-, sea-, and air-based missiles, will give way to improvised scenarios developed by new proliferators and smaller nuclear powers.[31]

Nuclear-capable short- and medium-range ballistic missiles are already commingled with conventional ground and tactical air forces. The advanced precision strike regime empowers a synergistic combination of indirect and direct fire support at longer ranges supported by information enhanced command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems. Against this enriched environment for long-range and accurate firepower, defenses must be smarter, faster, and multilayered for redundancy.

For the United States' Allies in Europe and Asia, regional adversaries pose a credible threat of nuclear and conventional first strike within minutes, which deprives the other side of unambiguous warning and accurate attack characterization. The avoidance of these regional nuclear wars may rise to the gold standard of deterrence for the first half of this century. In the current political environment, technologies for "theater" or regional missile defenses appeal to besieged leaders because they are a demonstration of action. This is especially the case as ballistic missile systems with advanced propulsion are becoming more survivable, reliable, mobile, and accurate—with the ability to strike targets over longer distances.[32]

Offenses may also evolve away from dependency on ballistic missiles as first-strike weapons. Cruise missiles offer precision-strike power from land, sea, and air launchers—and over a variety of ranges. They are armed with conventional or nuclear warheads. Cruise

29. Merideth Roaten, "Hypersonic Threat Spurs Investment in Space-Based Missile Tracking," *National Defense*, August 8, 2022, https://www.nationaldefensemagazine.org/.

30. David Vergun, "General Says Countering Hypersonic Weapons Is Imperative," DoD, May 10, 2023, https://www.defense.gov/.

31. Emmanuelle Maitre, "Arms Control and Delivery Vehicles: Challenges and Ways Forward," *Journal for Peace and Nuclear Disarmament* 5, no. 1 (2022); and Waheguru Pal Singh, "Why Missile Proliferation Is So Hard to Stop," *Bulletin of the Atomic Scientists*, June 28, 2016, https://thebulletin.org/.

32. Hensley et al., "Understanding the Indications"; and see also Jacob L. Heim, "The Iranian Missile Threat to Air Bases: A Distant Second to China's Conventional Deterrent," *Air & Space Power Journal* 29, no. 4 (July–August 2015), https://www.airuniversity.af.edu/.

missiles are highly survivable against ballistic missile attack, making states less dependent on the "use or lose" dilemma. They only require the mastery of first-generation information age technology.

Although viewed as second-strike weapons in many nuclear scenarios, conventional cruise missiles demonstrate their potential for prompt first strike. The United States uses cruise missiles to good effect in wartime, in punitive reprisals, and in coercive diplomacy. Such use began in the first Gulf War (1991) and continues to the present.[33] Future American conventional prompt global-strike weapons may include hypersonic weapons capable of speeds between five and fifteen times the speed of sound, but with increased accuracy.[34]

Cruise missile technology may be employed to adjust the intended flight pattern of ballistic missiles. This tactic is designed to complicate the task of the defender's BMD systems. Whether such a hybrid missile or a ballistic missile with a hypersonic glide vehicle can adapt in flight to the defender's tactics is a complicated command-and-control problem.

As noted, Putin and other Russian officials assert that no American missile defenses are permitted to override Russia's nuclear deterrent. Putin specifically refers to Russian technology that allows ballistic missiles to maneuver in flight. It is not entirely clear from these references whether it is the missiles themselves or the re-entry vehicle that maneuvers in response to defensive interceptors.[35] Maneuverable warheads are not a new technology, but interest may increase if missile defenses are deployed in significant numbers.

Russia has also indicated its plans to place greater emphasis on its own air and missile defense forces, even as it continues to express doubts about the intentions of the United States and NATO in this regard. For example, then-Russian Defense Minister Sergei Shoigu announced in August 2015 the creation of the Russian Aerospace Forces, bringing under a single command Russia's air force and its aerospace defense forces. According to Shoigu, "Air forces, anti-air, and anti-missile defenses, and space forces will now be under a unified command structure."[36]

Some experts said the reorganization was at least a partial reaction to the perceived risk of NATO attacks against Russia, including those based on prompt global-strike weapons.[37] Others point to both technical and management obstacles in standing up and operating the new command, including rivalries among generals for new ranks and positions.[38]

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33. Jonathan Beale and Jacqueline Howard, "What We Know about Strikes on Houthis and Strategy behind Them," BBC, January 12, 2024, https://www.bbc.com/.

34. Robert Beckhusen, "Russia's Future Air Force Could Resemble . . . The US Air Force," Medium, January 2, 2015, https://medium.com/.

35. See Richard Weitz, *Russian-American Security Cooperation after St. Petersburg: Challenges and Opportunities* (Carlisle, PA: Strategic Studies Institute, 2007).

36. Matthew Bodner, "Russian Military Merges Air Force and Space Command," *Moscow Times*, August 3, 2015, https://www.themoscowtimes.com/.

37. Franz-Stefan Gady, "Russia Creates Powerful New Military Branch to Counter NATO," *Diplomat*, August 7, 2015, https://thediplomat.com/.

38. Alexander Golts, "Russia's Aerospace Forces Will Never Take Off," *Moscow Times*, August 10, 2015, https://www.themoscowtimes.com/.

Interest in BMD technologies is as likely driven by political threat perceptions as it is the product of "eureka" moments in research laboratories. One of the principal dangers of nuclear weapons spread in Asia is that it could generate a reciprocal arms race in missile defenses, followed by an escalated competition in offenses, and so on. Although experts focus on the dangers of a quantitative arms race in Asia and the Middle East, the threat of a qualitative arms race is equally or more dangerous.

Absent controls over regional nuclear proliferation, the appeal of BMD against missiles of short- or medium-ranges will grow. Both Russia's war in Ukraine and Israel's war against Hamas offer important lessons in this area.[39] The real reassurance that these theater missile defenses provide shape both the offensive and defensive use of ballistic and cruise missiles, as well as drones. The interactions between those states building offensive capabilities and those building defensive capabilities are dynamic and often have second- and third-order consequences beyond the parties involved—often pulling the United States into the defense of an ally or friend.

## Caveats and Conundrums

All models of nuclear warfare are subjective, regardless of their pretensions to objectivity. In addition to the battlefield use of nuclear weapons in conflict, nuclear "warfare" can also include the "use" of nuclear weapons for the purpose of avoiding strategic war by means of deterrence. Following Carl von Clausewitz's advice, the strategist must acknowledge that all weapons have purposes dictated by state policy. In the hands of rational decisionmakers nuclear strike is not a preference.[40]

The exact political conditions under which a two-sided or multisided nuclear war might start are numerous and unpredictable. Once the door is opened to nuclear first use and retaliation, the admonitions of Clausewitz about the environment of war—characterized by uncertainty, friction, and chance—apply even more than they do to conventional war.[41]

These cautions about nuclear force exchange modeling are especially apropos when defenses are entered into the equation. The most interesting and perhaps effective defenses, from the standpoint of military-strategic effectiveness, have yet to be invented. Projections of future defense capabilities are limited to what is in development and the "what if," which is best represented as a spectrum of possibilities. The capabilities of offensive forces are comparatively well known because of extensive testing and field deployment. On the other

39. Carl Rehberg, "Integrated Air and Missile Defense: Early Lessons from the Russia-Ukraine War," 1945 [website], June 10, 2022, https://www.19fortyfive.com/; Jacob Nagel and Shachar Shohat, "Iron Dome Developers Set the Record Straight on Its Evolution," *Jerusalem Post*, April 8, 2021, https://www.jpost.com/; and Yohah Jeremy Bob, "From North to South, These Iron Dome Teams Allowed Israel to Control the Pace of War," *Jerusalem Post*, February 18, 2024, https://www.jpost.com/.

40. Carl von Clausewitz, *On War,* ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1984).

41. Stephen J. Cimbala, *Clausewitz and Escalation: Classical Perspective on Nuclear Strategy* (London: Routledge, 2014), 8–12.

hand, no one knows exactly how offenses and defenses will interact regarding the performance of weapons in combat. Antiballistic tests, for example, have a mixed record that make it difficult to project their success in conflict.[42]

As to the fear policymakers must address in a Hobbesian international system—and to paraphrase Leon Trotsky—you may not be interested in nuclear targeting, but nuclear targeting is interested in you. This is the danger of nuclear proliferation. With more international actors possessing nuclear weapons, there is the possibility of nuclear first use increasing. Yet, it is also equally possible that the acquisition of nuclear arms leads to greater conservatism and more risk aversion.[43] The exact instances in which the former or the latter is true are unsettled.

Another ambiguity regarding offense-defense interactions is that once defenses pass a certain threshold of capability relative to offenses, defenses become potentially first-strike weapons. For example, antimissile defenses, based in space and capable of neutralizing another state's early warning and communications satellites, would be a logical part of an enhanced nuclear first-strike capability. In this case, space-based BMD would behave as an antisatellite (ASAT) weapon engaged in precursor attacks before ballistic missiles are launched or arrive at their intended targets. In response to such a deployment of space-based BMD-ASATs by one state, an adversary might deploy space-based defensive antisatellite weapons to neutralize the ASATs of the provocateur.

In addition to the kinetic effects that might occur during offensive-defensive attacks, there are also what one military analyst calls nonkinetic technologies:

> Most non-kinetic threats—or the NKT spectrum—consist of silent, largely undetectable technologies capable of inflicting damaging, debilitating, and degrading physical and neural effects on its unwitting targets. This covert threat is best understood as something to be invoked via rapid surprise attack or as a stealthy forerunner to a massive kinetic follow-on attack.[44]

Unfortunately for military planners, the effectiveness of antimissile defenses—particularly those targeting missiles more advanced than those fired at Israel by Hamas, Hezbollah, and Iran—is difficult to know until they are employed in battle. The United States' Patriot Missile Defense System has the most extensive history of use in combat, which is one of improving success.[45]

42. "US Ballistic Missile Defense," Center for Arms Control and Nonproliferation, June 12, 2023, https://armscontrolcenter.org/; and Kelley M. Sayler, *Defense Primer: Ballistic Missile Defense*, In Focus 10541 (Washington, DC: CRS, updated January 30, 2024), https://crsreports.congress.gov/.

43. Nuno P. Monteiro and Alexandre Debs, "The Strategic Logic of Nuclear Proliferation," *International Security* 39, no. 2 (2014).

44. Robert McCreight, "444. Non-Kinetic Threats and the Threshold Spectrum of Strategic Endgame Warnings," *Mad Scientist Laboratory*, May 11, 2023, https://madsciblog.tradoc.army.mil/.

45. Missile Defense Project, "Patriot," Missile Threat, Center for Strategic & International Studies [CSIS], August 23, 2023, https://missilethreat.csis.org/.

Within the next decade, neither Russia nor the United States will likely prove capable of deploying defenses that nullify the greater portion of an adversary's nuclear deterrent. Indeed, their research and development bureaucracies and associated industries are unlikely to deploy missile defenses that can bend the curve even modestly. In other words, against realistic—although not necessarily realizable—defenses in the next decade or so, both Russia and the United States can remain confident that their retaliatory forces perform the assured retaliation or "assured destruction" mission of inflicting unacceptable societal damage. In addition, they will retain some additional weapons for attacks on the other side's retaliatory forces, other military targets, and value targets.

So why consider deploying defenses at all? Defenses perform more than one function. They can provide additional deterrence by increasing the number of Russian or American warheads needed to destroy the other's ICBM force, which increases the cost side of a cost-benefit calculus.[46] As one ballistic missile defense study notes, "The defenses don't even have to work very well; the uncertainty that they might work, or could become more capable in the future, are enough to trigger the effect."[47] Again, it is all about shaping the perception of an adversary that a strike may be less successful than hoped—or unsuccessful altogether.

Missile defenses can also serve to deny a rogue state the option of causing unacceptable first-strike damage to American or Russian territory. Under conditions such that deterrence might fail no matter how reliable American or Russian second-strike capability might be, defenses can provide insurance against societal damage. Of course, whether defenses are tasked with the denial of enemy objectives or as a supplement to deterrence, defenses can only partially substitute for the missions that offenses must perform. A secure nuclear second-strike capability remains the backbone of strategic nuclear deterrence.[48]

If Russian or American defenses are not necessarily superfluous, are they necessary? This depends more on politics than on technology. If political relations between the two states returns to a situation in which relations are not hostile and China agrees to come to the negotiating table, there is room for cooperative security measures on several fronts. This may include further reductions in operationally deployed strategic nuclear weapons and force restructuring that improves the prelaunch survivability of each nation's nuclear arsenal—reducing the advantage for pursuing a first strike. On defenses, the potential for cooperative security seems limited until a resolution to Russia's war in Ukraine is achieved.

Under better conditions, an attainable option could permit unilateral-reciprocal initiatives that limit the United States and Russia to restricted-scope national or theater missile defenses against states outside of Europe, and among the ranks of current or future nuclear powers hostile to the United States or Russia. The challenge is that those states other than Russia hostile to the United States are often supported by Russia—namely Iran. At the other end of

46. Matt Korda and Hans M. Kristensen, "US Ballistic Missile Defenses, 2019," *Bulletin of the Atomic Scientists* 75, no. 6 (2019), https://doi.org/.

47. Korda and Kristensen, 295.

48. Austin Long and Brendan Rittenhouse Green, "Stalking the Secure Second Strike: Intelligence, Counterforce, and Nuclear Strategy," *Journal of Strategic Studies* 38, no. 1 (2015), https://doi.org/.

the spectrum, Russia could collaborate with the United States and NATO on the development of national or theater BMD. This was President Ronald Reagan's offer with the Strategic Defense Initiative and later offered by President George W. Bush.[49] The Soviet Union and Russia said no. These options are far from possible in the present or in the near future.

It remains surprising that some still question whether stable nuclear deterrence between Russia and the United States is important.[50] The answer lies in geopolitics as related to the spread of nuclear weapons. Multilateral security in Asia and in Europe is simply inconceivable without bilateral political and military security, including both stable deterrence and reassurance, as between the United States and Russia, and soon, China.

The containment of nuclear proliferation in Asia and the return to a debellicized Europe require an end to the conflict in Ukraine and Russia's active commitment to military forbearance. Russia is a necessary, if always inconvenient, security partner for the United States and NATO—for selfish as well as for altruistic reasons in Washington and in Brussels.

## Conclusions

The Cold War and immediate post-Cold War experience of the United States with nationwide missile defenses was a potlatch of limited research and development resulting in modest deployments and limited military-strategic effect until well after the Cold War. New technologies may advance the state of the art for missile defenses, especially against threats of less than intercontinental or transoceanic ranges.

On the other hand, offenses will also take advantage of new technologies for circumventing defenses, including challenges to potential space-based missile defenses or space-located supports for ballistic missile defenses; and hypersonic speeds with maneuverability allowing little time for decision making and, in some cases, forcing delegation of decisions to AI systems preprogrammed for timely responses.[51] There is the additional uncertainty attached to the use of nonkinetic threats before or during kinetic warfare, either by prospective attackers or defenders.

Russia's annexation of Crimea in 2014 and its war of aggression against Ukraine, as well as the Sino-Russian political alignments and military cooperation of 2022–23, remind us that geopolitical surprises have a way of detouring diplomacy and smudging military-strategic complacency.[52] On the other hand, the performance by Russian military forces in Ukraine during the same period shows that Russia remains somewhat

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49. Vladislav Zubok, *Collapse: The Fall of the Soviet Union* (New Haven, CT: Yale University Press, 2021).

50. Alexey Arbatov, "Nuclear Deterrence: A Guarantee or Threat to Strategic Stability?," Carnegie Russia Eurasia Center, March 22, 2019, https://carnegieendowment.org/.

51. Michael Depp and Paul Scharre, "Artificial Intelligence and Nuclear Stability," *War on the Rocks*, January 16, 2024, https://warontherocks.com/; and see also Adam Lowther and Curtis McGiffin, "America Needs a Dead Hand More Than Ever," *War on the Rocks*, March 28, 2024, https://warontherocks.com/.

52. Ricardo Berrios and Andrew Bowen, *China-Russia Relations,* In Focus 12100 (Washington, DC: CRS, 2023), https://crsreports.congress.gov/; and Dmitry Gorenburg et al., *Russian-Chinese Military Cooperation* (Arlington, VA: Center for Naval Analyses, 2023), https://www.cna.org/.

behind NATO in its ability to conduct modern air-land battle in high-end conventional warfare—especially in the coordination of direct and indirect long-range fires, aviation, and ground forces.[53]

Notwithstanding the seriousness of the current threat posed by Russia to the rules-based international order in Europe, Russia's significance as the geostrategic pivot of Eurasia remains an important marker for American policy planning. Peace in Europe and Asia requires that the United States and NATO reestablish deterrence vis-à-vis Russia. It is difficult to push forward with a cooperative security agenda regarding nonproliferation, including the safety and security of weapons and fissile materials; nuclear arms controls; and the inclusion of Russia within Euro-Atlantic security structures, including missile defenses, if Putin or his successor believes NATO is not up to the fight of defending Europe.

53. Zoltan Barany, "What the West Still Gets Wrong about Russia's Military," *Foreign Affairs*, September 8, 2023, https://www.foreignaffairs.com/; and Seth G. Jones, Alexander Palmer, and Joseph S. Bermudez Jr., "Ukraine's Offensive Operations: Shifting the Offense-Defense Balance," CSIS, June 9, 2023, https://www.csis.org/.

# Disinformation and Entropy

## Leveraging AI in the Information Environment

José R. Davis

Considering the Air Force's burgeoning understanding of the information environment in an age of artificial intelligence (AI), effectively leveraging this technology in support of operations in this environment is crucial to success. This article examines the impact of disinformation and potential AI-driven counter-technologies on current and future Air Force operations. Together with improved metrics for assessments of operations, activities, and investments centered on entropy as understood in information theory, a proactive approach to such disinformation and countertechnologies reveals opportunities for the Air Force to win in today's AI era.

Since the term was first coined in the 1970s, *information warfare* has been an amorphous concept, predominantly used by the government and the US military, defined and molded by stakeholders from various backgrounds with different professional vernaculars.[1] Prior to 2017 and the announcement of information as the seventh Joint function, the Department of Defense on the whole had no formal information strategy or information objectives.[2] Similarly, the US Air Force's dispersed information warfare (IW) capabilities had "no comprehensive framework that allow[ed] them to unify their efforts in a way that provide[d] sufficient signal to noise ratio and effective engagement."[3]

Joint doctrine defines the information environment as "the aggregate of social, cultural, linguistic, psychological, technical, and physical factors that affect how humans and automated systems derive meaning from, act upon, and are impacted by information, including the

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1. Sandeep Mulgund, Memorandum for C2 of Operations in the Information Environment (OIE) Working Group, Subject: Definitions and Working Descriptions for Information-Related Terms, September 2020; Catherine A. Theohary, "Defense Primer: Operations in the Information Environment," In Focus 10771 (Washington, DC: Congressional Research Service, December 14, 2023), https://crsreports.congress.gov/; and Mike Dahm, "The Reality of War Should Define Information Warfare," *Proceedings* 147, no. 3 (March 2021), https://www.usni.org/.

2. *Joint Warfighting*, Joint Publication (JP) 1-1 (Washington, DC: Chairman of the Joint Chiefs of Staff [CJCS], August 27, 2023), III-25; and Charles R. Grynkewich, "Introducing Information as a Joint Function," *Joint Force Quarterly* 89 (2018), https://ndupress.ndu.edu/.

3. Andrew Caulk, "An Information Warfare Framework for the Department of Defense," *Air & Space Power Journal* 35, no. 1 (April 2021), https://www.airuniversity.af.edu/; and *Public Affairs*, Air Force Doctrine Publication (AFDP) 3-61 (Maxwell AFB, AL: Curtis LeMay Center for Doctrine Development and Education [LeMay Center], September 2020), 12, https://www.doctrine.af.mil/.

individuals, organizations, and systems that collect, process, disseminate, or use information."[4] The lack of a comprehensive framework allowing for unified efforts in this environment made it difficult for the US Air Force to deliver synchronized, practical effects.

Today, the landscape is different. A "complex and volatile global security environment presents profound challenges that erode US global influence and military advantage."[5] Adversaries have become adept at conducting operations below the threshold of armed conflict, which threaten the Department of the Air Force's (DAF) ability to conduct its five core missions—air and space superiority; intelligence, surveillance, and reconnaissance (ISR); rapid global mobility; global strike; and command and control.[6] As a recent RAND report notes, "The role of information and information technologies in strategic competition and military operations has evolved considerably in the first two decades of the 21st century."[7] The challenges of strategic competition are only accelerating with the rapid advancements of artificial intelligence (AI).

On November 17, 2023, the Defense Department released a strategy document on informational power, further codifying terminology and established programs for what is expansively understood as operations in the information environment (OIE), of which information warfare is an adversary-facing component.[8] These operations concern the manner in which information is communicated, transmitted, and processed in the information age. Information—understood as a unified, complex system in which a source pushing a message must overcome noise through a stable conduit to have the desired effect on a receiver—has forced the Air Force's information-related capabilities to become more cross-functional.

Many service functions that contribute to OIE, including public affairs and information operations, have gone through a seismic shift as operators have integrated and collaborated with each other to achieve cohesive effects in the information environment.[9] For example, public affairs, which is responsible for owning public communications and bringing to bear the public personas of institutions into the information environment, has become much more systematic in ensuring its doctrinal mandate of "work[ing] with information operations and strategic communications planners to coordinate and deconflict communication activities."[10]

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4. *Information in Joint Operations*, JP 3-04 (Washington, DC: CJCS, September 2022), GL-5.

5. Deputy Chief of Staff for Strategy, Integration, and Requirements, US Air Force [USAF], *USAF Operating Concept for Information Warfare*, v1 (Washington, DC: Department of Defense [DoD], March 30, 2022), 2.

6. Michelle Grisé et al., *Rivalry in the Information Sphere: Russian Conceptions of Information Confrontation* (Santa Monica, CA: RAND Corporation, November 2022), 9, https://doi.org/.

7. Grisé et al., 9.

8. "DoD Announces Release of 2023 Strategy for Operations in the Information Environment," DoD, November 17, 2023, https://www.defense.gov/.

9. Mary F. O'Brien, *Integration Imperative: Synchronization of Information Warfare Functions* (Washington, DC: Headquarters US Air Force [HAF], A2/6, February 10, 2021).

10. *Public Affairs*, JP 3-61 (Washington, DC: CJCS, August 2016), I–4.

Today, these various Air Force functions must continue to incorporate and adapt continued advancements in AI, particularly in the realm of generative AI, to provide commanders operational advantage through the information environment.[11] Natural language processing, which attempts to make human communication-like speech and text detectable by computers, and computer vision, which aims to teach computers to act or recommend action on issues based on information gleaned from digital images or other visual input, are and will have a profound impact on OIE, especially in the deployment of large language models (LLMs) and other deep-learning architectures that can masterfully achieve a wide range of tasks, from generating novel text to generating wholly unique images.[12]

Further complicating this situation is the fact that these advances in AI are being employed by Allies and adversaries alike. As a recent NATO report states, the world is entering into a new phase of manipulation in the IE, and "it remains unclear whether, in the long run, defenders or attackers will derive greater benefit from AI systems."[13]

Though general progress has been made in bolstering AI readiness across the service, the Air Force needs to target its AI research and development exclusively on operations for the information environment in order to realize the aim of the service's 2022 *Information Warfare Strategy*—namely, to "deliver automated and AI/ML [machine learning]-enabled tools to support rapid planning and assessment of IW."[14] An analysis of disinformation and AI-based mitigations and the application of entropy as understood by information theory provide options for the Air Force as it looks to win in operations in the information environment.

## Operations in the Information Environment and AI

The US Air Force formally defines operations in the information environment as "the sequence of actions that use information to affect behavior by informing audiences; influencing relevant external actors; and affecting information, information networks, and information systems."[15] Further, this understanding of information goes beyond the written or spoken word or even broadcast imagery; it perceives that all activities have a kind of signal that may deliver a message or communicate intent. The IE, for that matter, is more of an "intellectual framework" that assists in comprehending and describing "often-intangible factors" which affect the US military's operational environment.[16]

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11. JP 3-04.
12. David Morgan, "Using Large Language Models in the DoD Context," DAU [Defense Acquisition University], February 14, 2024, https://media.dau.edu/.
13. Rolf Fredheim, *Virtual Manipulation Brief 2023/1: Generative AI and its Implications for Social Media Analysis* (Riga, Latvia: NATO Strategic Communications Centre of Excellence [StratCom COE], June 2023), 3–12, https://stratcomcoe.org/.
14. *United States Air Force Information Warfare Strategy* (Washington, DC: HAF, July 8, 2022), 6; and Alexander Farrow and Victor Lopez, "AI Readiness in a US Air Force Squadron," *Air & Space Operations Review* 2, no. 2 (2023), https://www.airuniversity.af.edu/.
15. AFDP 3-61, 2.
16. JP 3-04, ix.

In an effort to formalize and integrate Air Force operations in the IE, the Air Force produced the above-referenced *Information Warfare Strategy* and an implementation plan in 2022, merging informational activities and investments across the enterprise.[17] The strategy aims to integrate information across all domains, providing "air component commanders options to modify tempo, timing, and speed of operations."[18]

The service has pushed other initiatives aimed at developing OIE in recent years, in alignment with Joint doctrine.[8] For example, in September 2019 the 16th Air Force became a component numbered air force, making it the only service entity at that level fully focused on information warfare, among its other cyber-related responsibilities.[19] By 2020, the DAF OIE working group had published an official memorandum describing definitions for information-related terms, aimed at clarifying the language used in OIE and providing a consistent lexicon for information-related capabilities.[20]

In 2021, the Air Force merged ISR with its cyber functions, establishing a new directorate postured to synchronize IW-related capabilities.[21] And by 2023, Air Combat Command had become the Air Force's lead major command for organizing, training, and equipping the force for IW.[22] This is only a small sample of recent, myriad initiatives within the Air Force implementing changes and policies for OIE, as outlined by service senior leaders, ranging across doctrine, organization, training, education, leadership, personnel, and policy.[23]

The service's strategy on OIE defines success as the institutionalization and operationalization of informational capabilities across the Air Force. One of the major components to this strategy is providing Airmen advanced tools and systems to deliver IW effects across the competition continuum: "Information Warfare capabilities must be supported by refined analytical methods such as optimization, simulation, decision analysis, artificial intelligence, machine learning, etc."[24]

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17. *USAF Information Warfare Strategy*; and *USAF Information Warfare Strategy: Implementation Plan* (CUI) (Washington, DC: Headquarters, Department of the US Air Force [DAF], May 2023). Note: the information referenced in the article is not CUI.

18. *USAF Information Warfare Strategy*.

19. Rabia Coombs, "The First Information Warfare Numbered Air Force Welcomes New Commander," Sixteenth Air Force (Air Forces Cyber), July 22, 2022, https://www.16af.af.mil/.

20. "Definitions and Working Descriptions for Information-Related Terms," memorandum, HAF, September 15, 2020.

21. O'Brien, "Integration Imperative," 1–4.

22. "ACC Co-Leads Effort to Hone Information Warfare Readiness," Air Combat Command, March 16, 2022, https://www.acc.af.mil/.

23. Coombs, "First Information Warfare"; O'Brien, "Integration Imperative"; George M. Reynolds, "Achieving Convergence in the Information Environment: Revising the Air Component Structure," *Air & Space Power Journal* 34, no. 4 (2020), https://www.airuniversity.af.edu/; and Sandeep S. Mulgund and Mark D. Kelly, "Command and Control of Operations in the Information Environment: Leading with Information in Operational Planning, Execution, and Assessment," *Air & Space Power Journal* 34, no. 4 (2020), https://www.airuniversity.af.edu/.

24. *USAF Information Warfare Strategy*, 6.

The OIE strategy has two phases: 2022 to 2025, and 2025 to 2029. Each of these phases explicitly directs the leveraging of artificial intelligence for OIE. Phase 1 calls for IW subdiscipline data to be integrated into the Air Force's data fabric, which provides enterprise capabilities that enable the sharing and reuse of data and data tools interconnecting AI users, data, environments, and resources across the Defense Department. Phase 2 calls for the delivery of automated and AI/ML-enabled tools to support rapid planning and assessments of IW.

Importantly, these two phases use whatever tools are available as the technology rapidly advances beyond current capabilities at the time of this writing.[25] One outstanding example of newly developed technology is NIPRGPT—a DoD-approved LLM that can sift through controlled unclassified information documents—developed by Dark Saber, a "software engineering ecosystem" across the Air Force that creates next-generation software capabilities.[26] This and future AI developments will maximize information advantages that ensure the successful employment of airpower in an ever-changing technological landscape.

This article discusses how AI could be leveraged for operations in the information environment, with a special focus on countering disinformation and on OIE assessments, including a new model using information theory.

## Inoculating against Disinformation

*AI will probably have the most impact on information warfare, which could still be highly destructive. We got a glimpse of this when the Russian government interfered with the 2016 presidential election.*

Tom Taulli, *Artificial Intelligence Basics: A Non-Technical Introduction*[27]

### *The Problem*

Disinformation is the deliberate spread of harmful, false, and misleading information.[28] Disinformation is misinformation with a nefarious bent. The most redolent example of disinformation, familiar to many, occurred in 2016 when the Russian government propagated dubious information via social media to manipulate the results of the US presidential election.[29] Disinformation is a plague of the modern information age, exacerbated now by the advancements of generative AI.

25. Morgan, "Large Language Models."

26. "Dark Saber," Dark Saber, accessed May 19, 2024, https://devilops.mil/.

27. Tom Taulli, *Artificial Intelligence Basics: A Non-Technical Introduction* (Berkeley, CA: Apress, 2019), 79.

28. Jon Roozenbeek and Sander van der Linden, *Inoculation Theory and Misinformation* (Riga: NATO StratCom COE, October 2021), https://stratcomcoe.org/.

29. "Grand Jury Indicts 12 Russian Intelligence Officers for Hacking Offenses Related to 2016 Election," US Department of Justice, July 13, 2018, https://www.justice.gov/.

Further, research finds that "people who have been exposed to [disinformation] may continue to rely on it, even if it has been debunked—a phenomenon known as the "continued influence effect."[30] The ability of disinformation to control an individual's cognitive understanding of the world is immensely powerful. And debunking disinformation before it takes root has become exceptionally more difficult with the ability of generative AI to produce manipulative content at scale.

As one RAND report notes, "The world may remember 2022 as the year of generative artificial intelligence: the year that large language models, such as OpenAI's GPT-3, and text-to-image models, such as Stable Diffusion, marked a sea change in the potential for social media manipulation."[31] Moreover, today's AI is tomorrow's least capable AI, as quantum or neuromorphic computing could increase computational power for generative AI. Indeed, US adversaries no longer need to rely on an army of human internet trolls to promulgate disinformation. AI is doing it for them.

In a report by the Center for Countering Digital Hate, researchers discovered AI tools were generating successful images promoting voting disinformation in 59 percent of their tests. These were highly realistic fake images from simple text-based prompts.[32] Further, there is evidence bad actors are using these AI tools now for disinformation. Researchers in the same report saw a drastic upsurge of community notes on X (the platform formally known as Twitter)—for example, user-generated fact-checks added to some posts—by an average of 130 percent per month, demonstrating how disinformation featuring AI-generated images is increasing quickly on social media.[33] In fact, one of the first case studies of voting disinformation, perpetuated by AI and manifesting in campaign videos and automated calls, is playing out at the time of this writing, during the 2024 Indian general election.[34]

## *Potential Solutions*

This concern about disinformation in relation to the rapid advancements of generative AI partially motivated President Joseph R. Biden's Executive Order 14110. The order ensures the safe, secure, and trustworthy development and use of artificial intelligence "by

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30. Roozenbeek and van der Linden, *Inoculation Theory*; and Stephan Lewandowsky et al., "Misinformation and Its Correction: Continued Influence and Successful Debiasing," *Psychological Science in the Public Interest* 13, no. 3 (2012): 8, https://doi.org/.

31. William Marcellino et al., *The Rise of Generative AI and the Coming Era of Social Media Manipulation 3.0* (Santa Monica, CA: RAND Corporation, November 2023), 1, https://doi.org/.

32. *Fake Image Factories: How AI Image Generators Threaten Election Integrity and Democracy* (Washington, DC: Center for Countering Digital Hate, March 2024), https://counterhate.com/.

33. *Fake Image Factories*.

34. Meryl Sebastian, "AI and Deepfakes Blur Reality in India Elections," BBC, May 15, 2024, https://www.bbc.com/.

establishing standards and best practices for detecting AI-generated content and authenticating official content." [35] The order directs sweeping actions to protect Americans from the potential risks of AI systems, one of which is deceptive, AI-generated content.

Further, the order directs the US Department of Commerce to develop content authentication and watermarking tools for all federal agencies to use, including the Defense Department. These tools will "make it easy for Americans to know that the communications they receive from their government are authentic."[36] Although this order was recently issued, the US government has been focused on AI ethics and safety dating back to then-President Donald Trump's Executive Order 13859.[37]

Private industry has already begun to experiment with watermarking techniques. In August 2023, Google's DeepMind developed SynthID, which embeds modifications to individual pixels in photos and videos so watermarks are unseen to the human eye, though detectable by computers.[38] Yet in terms of OIE and the continued influence effect, watermarking may be insufficient for curtailing disinformation, largely due to the immense and iterative work needed to make it sufficiently robust, on top of the needed policies to drive its adoption. Even Google has acknowledged that SynthID is "not foolproof against extreme image manipulation."[39]

As Massachusetts Institute of Technology (MIT) Professor Aleksander Madry stated in his testimony before Congress, "We need to start to be more wary than ever about how information reaches us, its trustworthiness and its ability to persuade us."[40] This call for vigilance is heightened in the context of OIE, as DAF equities focus on combating the spread of disinformation.

Artificial intelligence researchers at MIT have developed various techniques that make an image resistant to AI-powered manipulation by adding to the image a carefully crafted, imperceptible perturbation—a small modification in pixels picked up only by a computer.[41] Inoculating an image not only prevents an AI model from trying to manipulate it, but also stymies the spread of disinformation by prebunking it. This approach is twofold, technical in disrupting generative models and psychological in preempting disinformation before it can spread.

35. "Fact Sheet: President Biden Issues Executive Order on Safe, Secure, and Trustworthy Artificial Intelligence," White House, October 30, 2023, https://www.whitehouse.gov/; and Exec. Ord. No. 14110, 88 Fed. Reg. 75191 (October 23, 2023).

36. Exec. Ord. No. 14110.

37. Exec. Ord. No. 13859, 84 Fed. Reg. 3967 (February 11, 2019), https://trumpwhitehouse.archives.gov/.

38. Tom Gerken and Philippa Wain, "Google Tests Watermark to Identify AI Images," BBC, August 29, 2023, https://www.bbc.com/.

39. Gerken and Wain.

40. *Artificial Intelligence and Human Rights, Hearing before the Subcommittee on Human Rights and the Law* (testimony of Aleksander Madry, Cadence Design Systems professor of computing, Massachusetts Institute of Technology [MIT]), 118th Cong. (2023), https://www.judiciary.senate.gov/.

41. Rachel Gordon, "Using AI to Protect against AI Image Manipulation," MIT News, July 31, 2023, https://news.mit.edu/.

In the psychological sense, the idea of prebunking and creating a "vaccine" against disinformation derives from a 1960s framework called inoculation theory, advanced by social psychologist William McGuire.[42] Inoculation theory holds that "by exposing individuals to a persuasive message that contains weakened arguments against an established attitude (e.g., a two-sided message, or a message that presents both counterarguments and refutations of those counterarguments), individuals would develop resistance against stronger, future persuasive attacks."[43] Researchers applied this inoculation theory in 2017 within the context of online misinformation.[44] Studies have shown that both partial and full inoculation are effective at countering the effects of misinformation exposure.[45]

The virtue of this approach is in its forced exercise of individuals' rational faculties, allowing them to resist disinformation freely and in their own time, very much like a body's immune system resists a virus on its own after a benign exposure from an immunization. Rational deliberation and the encouragement of people to think through information foster accurate belief formation, allaying the development of partisan bias and susceptibility to misinformation.[46]

Prebunking of and immunization from misinformation have also been seen in current events, when the Biden administration publicly released intelligence information of Russia's various military activities and mobilization throughout the fall and winter of 2021, warning of Russia's building aggression leading up to its February 2022 invasion of Ukraine.

The technical potential of nefarious generative AI could neutralize the potency of prebunking. Fortunately, generative AI can also be employed defensively, in the same way as inoculation theory is used socially. One MIT study funded by the DAF-MIT AI Accelerator program proposes using the MIT-developed AI technique referenced above, dubbed PhotoGuard, which immunizes images and video against the power of diffusion models' ability to manipulate content.[47]

Diffusion models have emerged as impressive tools for generating realistic images, currently surpassing the quality of other image-generating models such as generative adversarial networks. Using a stochastic differential process—which uses random vari-

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42. William J. McGuire, "A Vaccine for Brainwash," *Psychology Today* 3, no. 9 (1970).

43. Josh Compton, Ben Jackson, and James A. Dimmock, "Persuading Others to Avoid Persuasion: Inoculation Theory and Resistant Health Attitudes," *Frontiers in Psychology* 7 (2016): 2, https://doi.org/.

44. Sander van der Linden et al., "Inoculating the Public against Misinformation about Climate Change," *Global Challenges* 1, no. 2 (February 2017), https://doi.org/; and Stephan Lewandowsky and Sander van der Linden, "Countering Misinformation and Fake News through Inoculation and Prebunking," *European Review of Social Psychology* 32, no. 2 (2021), https://doi.org/.

45. van der Linden et al.; and Meghan Fitzpatrick, Ritu Gill, and Jennifer F. Giles, "Information Warfare: Lessons in Inoculation to Disinformation," *Parameters* 52, no. 1 (2022): 111, https://press.armywarcollege.edu/.

46. Bence Bago, David G. Rand, and Gordon Pennycook, "Fake News, Fast and Slow: Deliberation Reduces Belief in False (But Not True) News Headlines," *Journal of Experimental Psychology* 149, no. 8 (August 2020), https://doi.org/.

47. Hadi Salman et al., "Raising the Cost of Malicious AI-powered Image Editing," in *PMLR: Proceedings of Machine Language Research* 202 (2023), https://doi.org/.

ables—diffusion models excel in generating and editing images using textual prompts, such as that offered by DALL-E, Stable Diffusion, and Midjourney.[48]

The study mentioned above focused on latent diffusion models, which differ from standard diffusion models mainly in encoding the input image. This approach leverages adversarial perturbations to immunize images, forcing the latent diffusion models to generate images unrelated to the original immunized-input images, demonstrating the ability to immunize images from becoming deepfakes. The study's quantitative results employing PhotoGuard showed success in generating noticeably different images between immunized images and nonimmunized images. Just as inoculation theory in the social sense provides a degree of protection from disinformation, the researchers thus demonstrated AI can provide a degree of protection to content itself from being used for disinformation and deepfakes: "In this paradigm, people can thus continue to share their (immunized) images as usual, while getting a layer of protection against undesirable manipulation."[49]

CariNet is another model developed to provide inoculation against disinformation.[50] Also developed at MIT, CariNet is a novel, semi-supervised artifact attention module that amplifies artifacts—distortions or unwanted features introduced into an image or video during processing—in deepfake imagery to make them more detectable by people. Artifacts in deepfakes vary depending on the technology and methods used to create them. For example, an artifact can be in a manipulated video due to inconsistencies in frame rates, or the speed at which an image is shown, in which a deepfake may not perfectly match the frame rate of the original video, causing stuttering or unnatural movements. CariNet generates "deepfake caricatures"—that is, distorted versions of deepfakes—which magnify unnatural movements in imagery caused by artifacts, hence making them obviously apparent to the human eye.

Importantly, the researchers in various experiments found that exposing deepfakes by amplifying artifacts increases detection rates by people, more so than text-labeled warnings of a deepfake. Moreover, CariNet empowers individuals to exercise their own judgment on the trustworthiness of an image, as opposed to a forced denouncement from a label. Empowering individual judgment strengthens one's immune system against the virus of disinformation: "A system which allows humans to directly detect if a video is doctored will empower them to assess for themselves whether to trust the video."[51]

The engineers of both CariNet and PhotoGuard emphasize the necessity of continued cooperation between developers of these preventative deepfake models and those entities that are determined to curtail the spread of disinformation, such as the US government.[52]

48. Gundars Bergmanis-Korāts et al., *AI in Support of StratCom Capabilities* (Riga: NATO StratCom COE, January 2024), 43, https://stratcomcoe.org/.

49. Salman et al., "Raising the Cost," 1.

50. Camilo Fosco et al., "Deepfake Caricatures: Amplifying Attention to Artifacts Increases Deepfake Detection by Humans and Machines," arXiv, Cornell University, last revised April 10, 2023, https://doi.org/.

51. Fosco et al., 9.

52. Salman et al., "Raising the Cost," 8.

Adversaries and nefarious agents could invest in building their own models or upgrading current models, which could make PhotoGuard or CariNet obsolete. Employing these preventative models is not a one-off action, but a matter of continuous development as an element of IW above and below the threshold of armed conflict, whether with PhotoGuard, CariNet, or similar models and research.[53]

Operational advantage or disadvantage is clearly driven by information. The 2004 Abu Ghraib scandal showed how the power of photographs and information could severely hamper US military operations, as insurgents used the imagery as a propaganda tool to fuel greater Iraqi rage and resistance.[54] In a future 2034, AI-generated scandalous and utterly fabricated imagery of US forces could potentially be widely circulated and disseminated, say of an F-35's indiscriminate targeting of civilians, posing a possible serious threat to US military operations. AI's ability to unravel the dichotomy of fact or fiction will undermine airpower.

Fortunately, as discussed, generative AI can be used on the right side as well. The Defense Visual Information Distribution Service (DVIDS), which makes available real-time, broadcast-quality video and still images to media sources, offers one example of application.[55] But uploaded content is also accessible to those who intend to sow disinformation. Yet whether by adding perturbations or amplifying artifacts, DVIDS content could be immunized against mal-intended generative AI, thereby preventing disinformation from taking root.

## Entropy, Information, and Assessments

As the Air Force coalesces around a common understanding of OIE, across information-related capabilities and information warfare capabilities, a problem remains. How does the Air Force measure the effectiveness of its operations, activities, and investments in the information environment, across the spectrum of its contributions to the Joint force? To add to the challenge, much of this activity in today's age of strategic competition occurs below the level of armed conflict. Tying action to outcome in the information space is complex and not well-understood, making assessments more challenging to execute successfully.[56]

Current research is developing novel approaches to address this challenge of tying action to information in assessing the IE. One approach advocates perception analysis. Leveraging a review of current literature and interviews with US Air Forces Europe–Air Forces Africa and Pacific Air Forces subject matter experts, one analysis proposes a perception assessment

53. Melissa Heikkilä, "This New Data Poisoning Tool Lets Artists Fight Back against Generative AI," *MIT Technology Review*, October 23, 2023, https://www.technologyreview.com/.

54. Lene Hansen, "How Images Make World Politics: International Icons and the Case of Abu Ghraib," *Review of International Studies* 41, no. 2 (2015), https://doi.org/.

55. "About DVIDS," DVIDS [Defense Visual Information Distribution Service], accessed May 22, 2024, https://www.dvidshub.net/.

56. Katherine A. Batterton, "Operation Assessment in Strategic Competition: Measuring Chinese Communist Party Perceptions" (seminar thesis, Air University, Maxwell AFB, AL, April 2023), 16.

framework "encompass[ed] in three integral components: attention intensity, image/sentiment, and thematic/issue dimensions."[57] This framework takes as a given that a specific message sent may not be interpreted as intended by the receiver. The potential of this approach is in its fundamental acknowledgment of the "complex, nonlinear, interactive, and unpredictable nature of social human interactions."[58]

Another approach to assessments of the OIE called influence quantification (IQ) is purpose built for detection of disinformation narratives. The IQ framework employs "scalable, accurate, and automated discriminants to identify covert foreign influence early in the IE."[59] These discriminants are unusual behaviors or trends that help weed out nefarious actors. This approach is built on network causal inference—that is, in measuring the influence of a source spewing information. Influence quantification can quantify the spread of sentiment through narrative formulation and detection, providing information-related capabilities and IW practitioners meaningful measures of effectiveness.[60]

At the core of IQ's narrative detection is its employment of transformer-based natural language processing for semantic clustering in the IE. By using AI to cluster and sift through copious amounts of data in the form of natural language, IQ can then calculate a causal influence score identifying key influencers propagating information in a network. Interestingly enough, not only can IQ be used defensively for combating disinformation, but it can also be employed offensively for strategic communications.[61]

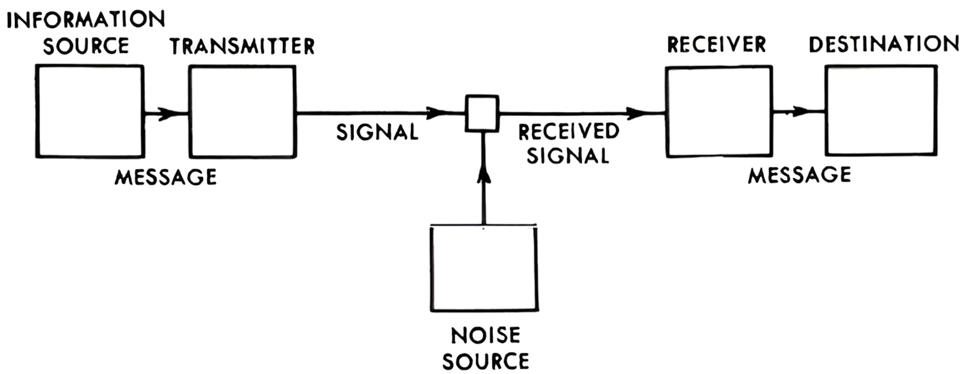


**Figure 1. A mathematical model of communication**

57. Batterton, 16.

58. Batterton, 8.

59. "Counter Influence Operations Using AI and Causal Inference, with Ethical Considerations," Recent Advances in AI for National Security (RAAINS) Conference, MIT Lincoln Laboratory, Lexington, MA, November 15–17, 2022.

60. Edward Kao, "Influence Quantification for Counter-IO" (slide presentation, RAAINS Conference, November 2022).

61. Stephen T. Smith et al., "Automatic Detection of Influential Actors in Disinformation Networks," *Proceedings of the National Academy of Sciences* 118, no. 4 (2021), https://doi.org/.

Further novel approaches are needed to develop assessment metrics for OIE that are common and useful across information-related and IW capabilities. Surely, each functional capability and every information-related capability have their own measures of success within their respective silos. But as silos are torn down to enhance OIE, IW capabilities need a common metric to measure their efforts toward singular operations, activities, and investments, such as any large-scale exercises the Air Force conducts.[62] In that vein, this article proposes a new metric for the IE, in the form of entropy, as defined under information theory.

Such entropy is the measurement of information as uncertainty or randomness in a channel or a system. The idea of conjoining entropy and information was pioneered by Claude Shannon in *The Mathematical Theory of Communication*.[63] Working at Bell Labs to enhance telecommunications, Shannon was keenly interested in engineering a communications system that could effectively transmit a message through a medium, despite noise and other obfuscations. As a communications engineer, he focused on the technical problem of communication, free of a message's semantic import or connotations, and wanted to mathematically measure how a message could be successfully transmitted. This was the impetus for the development of his idea of entropy as uncertainty.

IE complexity is directly related to the variety of activities present within a complex system. This complexity may be represented numerically using Shannon's entropy formula:

$$H(P) = -XP(i)log2P(i)$$

In sum, the variables calculate the expected amount of information (or uncertainty) in a probability distribution, considering all possible events and their respective probabilities. Stated in another way, "with equally likely events there is more choice, or uncertainty, when there are more possible events."[64]

More information yields greater uncertainty, more choice, and hence more entropy. With increased entropy, there is a greater need for redundancy in a channel, especially in terms of effectively communicating a message. Ultimately, with increase of information entropy, complexity scales to increase randomness to the point of collapse of the signal—or in terms of OIE, the inability to communicate a message effectively.

Shannon used natural language as an example of entropy in information theory. The redundancy of ordinary English is approximately 50 percent, which means half of English is determined by the structure of the language—for example, grammar—and half is chosen freely. Think crosswords or Wheel of Fortune or even a mobile phone's autocomplete text function: The more letters obtained, fewer choices become available, as one homes in on a handful of words.

62. JP 3-04, 115.

63. Claude E. Shannon and Warren Weaver, *The Mathematical Theory of Communication*, Illini Books ed. (Urbana: University of Illinois Press, 1963).

64. Shannon and Weaver, 49.

Entropy as a metric has been shown to be an effective and informative tool for various types of researchers across myriad fields.[65] For instance, cross entropy is used as a loss function in deep neural networks to adjust model weights during training, increasing the accuracy of the model's outputs. Entropy has also been used as a measure of behavioral regularity in studies "uncover[ing] the intricate relationship between habit formations and digital routines," specifically social media habits.[66]

One such study looks at how habits manifest in the digital space, validating the entropy metric as effective in predicting long-term behavior.[67] Within a defense context, entropy has been applied by special operations forces to improve weighting schemes for ranking terrorists during target analysis.[68] In the same sense, entropy can be applied as a common metric for OIE, providing practitioners a quantifiable and predictive way to measure the IE.

Apart from communicating a message, as depicted in figure 1, entropy applies to OIE because the information environment is a complex system. Due to higher entropy, highly complex systems require more cognitive effort to manage and are more cognitively stressful for system participants who are pursuing goals.[69] In this way, cognitive imbalances or disparities by system participants may be inferred from system entropy measures.

For example, information warfare capabilities such as public affairs or information operations could use the information-theory-based notion of entropy to inform their communications strategy by way of observing the IE: If the system in a current state has less information—that is, less entropy—then hypothetically it is the most optimal time for communicating to key audiences. Conversely, for IW capabilities such as weather or ISR, systems with more entropy are optimal because of the wealth of intel and information that can be reaped. This is an example of how entropy as a common metric for OIE can be cross-functional across IW capabilities and information-related capabilities.

Similar benefits could be gained from this metric in terms of key leader engagements. These engagements help commanders create effects in the information environment that can result in a decisive advantage over adversaries and gain rewarding opportunities with Allies and partners. The more complex systems become—that is, the more entropy present—the more likely it is that humans deploy simplifying heuristics. For example, when there is too much information circulating in the information environment, it is hypothetically more effective for the senior leader to keep their messages and engagements simple and short, so they gain better traction toward achieving key-leader-engagement

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65. Simon DeDeo et al., "Bootstrap Methods for the Empirical Study of Decision-Making and Information Flows in Social Systems," *Entropy* 15, no. 6 (2013), https://doi.org/.

66. Amir Tohidi Kalorazi, "Habit Formation and Political Persuasion: A Behavioral and Statistical Approach" (PhD dissertation, MIT, September 2023), 3, https://lids.mit.edu/.

67. Kalorazi.

68. William P. Fox et al., "Using the Entropy Weighting Scheme in Military Decision Making," *Journal of Defense Modeling and Simulation* 17, no. 4 (2020), https://doi.org/.

69. Brian Russell and John Bicknell, *The Coin of the Realm: Understanding and Predicting Relative System Behavior*, white paper, Information Professionals Organization, January 24, 2023, https://information-professionals.org/.

goals. Entropy, in this case, could help improve key-leader-engagement timing and improve engagement dossiers to maximize opportunity for favorable outcomes.

Research shows that human beings can only manage so much information. Too much information—too much entropy—can lead to confusion or disorder.[70] Applying Occam's razor—the principle that the simple explanation is preferred to the more complex—to states of higher entropy could be beneficial for public affairs or information operations, where reducing complexity could improve messaging.

Measuring entropy in the information environment requires a lot of data. Fortunately, advancements in machine learning and scalable data-processing systems have made this possible. Using the wealth of data from the Global Database of Events, Language, and Tone (GDELT) project could be a solution. Supported by Google Jigsaw, GDELT "monitors the world's broadcast, print, and web news from nearly every corner of every country in over 100 languages and identifies the people, locations, organizations, themes, sources, emotions, counts, quotes, images and events driving our global society every second of every day, creating a free open platform for computing on the entire world."[71] Using GDELT, entropy could be measured within the IE, which could be useful for information-related capabilities in gauging their impact supporting Air Force operations, activities, and investments.

As nascent as operations in the information environment are, a challenge exists in effectively assessing the expanse of the IE, across the spectrum of information-related and information warfare capabilities. Artificial intelligence can help the Air Force overcome this challenge. Assessing the IE is imperative and a priority of the Joint force.[72] Entropy as a metric—coupled with machine-learning models that can rapidly assimilate the surfeit of open-source information in the mediascape—is one example of a metric that IW and information-related capabilities could use to assess their impact before, during, and after military operations, activities, and investments.

## Conclusion

Information acts upon the sociopolitical structures of nation-states in profound ways. With this in mind, the Defense Department takes operations in the information environment seriously and strategically, as information directly impacts commanders' operational environments and the employment of kinetic forces. With rapid advancement, AI too will affect society in profound ways. As one AI expert contends, the potential and problem of

70. John Bicknell and Martin Jetton, *Cognitive Arbitrage: Complexity, Variety and Human Cognitive States Are Related*, white paper, Information Professionals Organization, December 6, 2023, https://information-professionals.org/.

71. "Watching Our World Unfold," GDELT [Global Database of Events, Language, and Tone] Project, accessed July 17, 2024, https://www.gdeltproject.org/.

72. JP 3-04, VI-1.

artificial intelligence is not only one of technology, but also of society.[73] Today's concern is about AI's ability to generate deepfakes and promulgate disinformation. But tomorrow's concern may be related to AI's ability to create real relationships with human beings, whatever that may entail.

As some computer science researchers and humanists have argued, "computer systems designed explicitly to exhibit human-like intentionality (seeming to be about and directed toward the world) represent a phenomenon of increasing cultural importance."[74] AI is often seen through a technical lens, with all the underlying algorithms and engineering of data involved. This view is especially prominent in the Air Force, considering the service's bent toward technocracy. But as some researchers propose, it is time to adopt a humanistic framework of AI that seriously considers how society should interpret a machine's emerging ability to signal intentionality in its actions and behaviors, beyond just chalking up mistakes to generative AI's propensity to hallucinate.[75]

As the Department of the Air Force directs AI research specifically on OIE, it should adopt a framework that converges technical prowess and societal impact. The AI tools for propagating disinformation are becoming dangerously more sophisticated, while the means of combating AI disinformation is increasingly a critical social responsibility not just a technical problem.[76] AI has the potential to propel or pulverize informational advantage for the Joint force. Evidence is clear that disinformation harms the US military's ability to leverage the IE for operational advantage. Furthermore, information's impact on operations needs to be measured: implementing metrics based on entropy as understood by information theory could be one of those measures. In this way, the military—and specifically, the US Air Force—can more effectively collaborate across functions and capabilities as it conducts information warfare in an age of AI.

73. Alger Fraley, *The Artificial Intelligence and Generative AI Bible: From Understanding the Basics to Delving into GANs, NLP, Prompts, Deep Learning, and Ethics of AI* (New York: AlgoRay Publishing, 2023).

74. Jichen Zhu and D. Fox Harrell, "Narrating System Intentionality: Copycat and the Artificial Intelligence Hermeneutic Network," *Leonardo Electronic Almanac* 17, no. 2 (2012): 160, https://groups.csail.mit.edu/.

75. Zhu and Harrell.

76. Henry Kissinger, Eric Schmidt, and Daniel Huttenlocher, *The Age of AI and Our Human Future* (New York: Little, Brown, and Company, 2021), Kindle ed., 96.

# An Integrated Space Test Lexicon

## A Taxonomy for the Integrated Test and Evaluation of Space Systems

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The proposed Integrated Space Test Lexicon is intended to amalgamate the numerous definitions of *integrated test* (IT or IT&E), *developmental test* (DT or DT&E), and *operational test* (OT or OT&E) into unified, service-wide definitions, aligned with the *Space Test Enterprise Vision*. Refining such definitions will help distill the core characteristics of these fundamental test types to first identify space system activities composing what is traditionally known as DT and OT, then to provide a means of how these activities fit into the IT paradigm and support space system development. In forging a common understanding of how DT and OT support space systems and capabilities, this lexicon will facilitate the foundation for an IT architecture, specifically the National Space Training and Testing Complex and the larger enterprise-level operational test and training infrastructure.

In March 2022, the US Space Force released its guiding document, *Space Test Enterprise Vision*, where the service laid out its plan of meeting current and future needs. Specifically, the Space Force must integrate operational and developmental space test and evaluation (T&E) activities to meet the challenges posed by the growing threat environment, the rapid emergence of new technologies and capabilities, and the small size of the Space Force. Using the Space Capstone Publication *Spacepower* as guidance, the US Space Force test enterprise strives to address these challenges and "drive data-informed decisions at speed, maximizing the Service's flexibility and efficiency in delivering space-based capabilities for the Joint Force and the nation."[1]

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1. *Space Test Enterprise Vision* (Washington, DC: US Space Force [USSF], 2022), 1, https://www.spaceforce.mil/; and *Spacepower: Doctrine for Space Forces*, Space Capstone Publication (Washington, DC: USSF, 2020).

The Space Force's approach to test and evaluation is centered on the concept of *integrated test* (IT or IT&E)—generally, the consolidation of testing efforts across agencies and the acquisitions cycle. The Space Force will integrate *developmental test* (DT or DT&E) and *operational test* (OT or OT&E) activities—generally, the testing of equipment, munitions, and weapons in the field, and the testing of systems design and performance, respectively—as much as possible "across a capability's life cycle and throughout the test enterprise encompassing organizations, workforce, infrastructure, acquisitions, and operations."[2]

As the number and capabilities of spacefaring countries have increased, the United States must improve its testing to retain its relative advantage across the space domain. Through integrated testing, the Space Force aims to bridge the developmental test-operational test divide by introducing operational perspectives early, simultaneously integrating and enhancing warfighting capabilities.

Considering the lack of consensus on the definitions of these fundamental test types, this article proposes streamlined definitions that align with the *Space Test Enterprise Vision* to identify what are traditionally known as DT and OT and demonstrate how these fit in the IT paradigm and support space system development. Such a lexicon provides a common understanding of how DT and OT support space systems and capabilities within IT. In turn, this understanding will facilitate the foundation for an IT architecture, specifically for the National Space Training and Testing Complex (NSTTC), and the overarching operational test and training infrastructure (OTTI) architecture.

## Background

The *Space Test Enterprise Vision* asserts IT "is the collaborative, tailorable, and responsive testing approach to provide shared data for independent evaluation of system performance, effectiveness, suitability, sustainability, and survivability."[3] Testing in the Space Force will be integrated across all levels, both strategic and tactical, from enterprise and system-of-systems level down to a single system and component levels.[4]

Throughout the entire system life cycle—from requirements definition to asset sustainment—testing will involve the individual test professional, who will hold the novel responsibility of providing the resulting IT data to both developmental and operational stakeholders. Testers should be as familiar with programmatic milestones as they are with operational tactics and potential utility. They will be intentionally sourced via workforce crossflow among acquisition, test, and operational professionals, fostering a test culture that promotes Joint warfighter influence upon each system's development and employment.

This crossflow is enabled by the NSTTC, the national network of interconnected, scalable, and distributed range facilities providing realistic threat informed test and

2. *Space Test Enterprise Vision*, 1.
3. *Space Test Enterprise Vision*, 3.
4. *Spacepower*; and Shawn N. Bratton and James P. Seballes, *Vision for: The National Space Test and Training Complex* (Peterson SFB, CO: Space Training and Readiness Command, 2022).

training environments for space warfighters found within the overarching OTTI.[5] The OTTI (fig. 1) is the overarching enterprise-level collection of testing and training assets that includes T&E, operational training, tactics development activities, and the NSTTC. This infrastructure includes blue force devices/trainers/simulators, live/synthetic aggressor capabilities, live and synthetic ranges/environments, and facilities/network that contain and connect OTTI systems.[6]

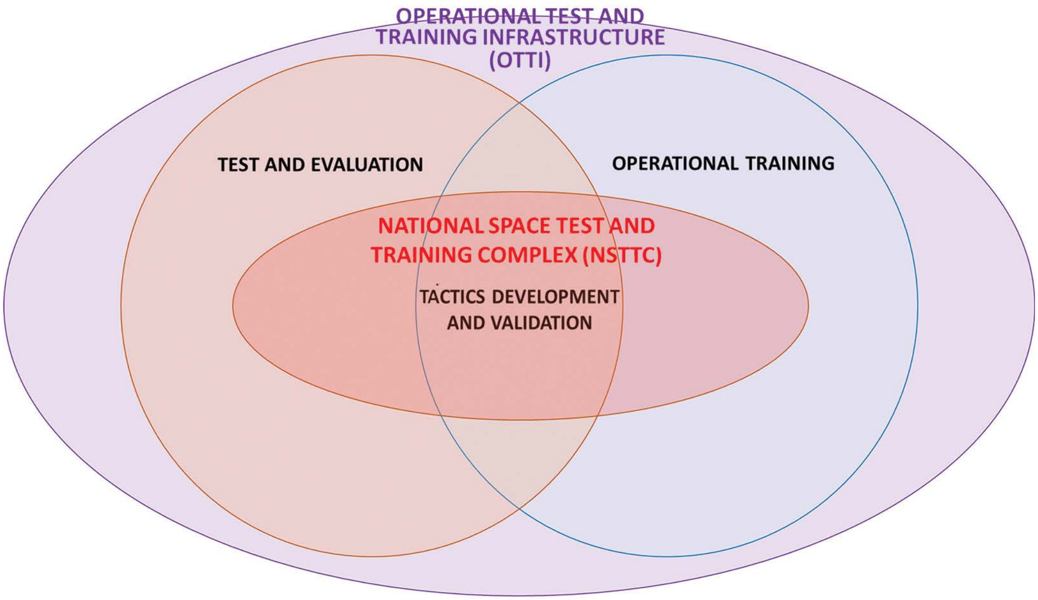


**Figure 1. The Operational Test and Training Infrastructure**

The terms developmental test and operational test are intentionally used to help bridge the gap between traditional practices and the intent of integrated test per the *Space Test Enterprise Vision*. The proposed lexicon will help develop a common understanding of how DT and OT support space systems and capabilities within IT, and in turn, this understanding will facilitate the foundation for an IT architecture, specifically the NSTTC and OTTI.

## Integrated Test Concept

The concept of IT originated via the 1990s acquisition reforms, namely, the 1994 Federal Acquisition Streamlining Act, the 1996 Federal Acquisition Reform Act, and the

5. Bratton and Seballes.
6. USSF/TE, "OTTI vs NSTTC Graphic" (Washington, DC: Department of the Air Force, 2023).

1996 Information Technology Management Reform Act.[7] The goals of the first were threefold: (1) to reduce unique purchasing requirements; (2) to use simplified acquisition procedures for low-income procurement to a greater degree; and (3) to accelerate the acquisition of commercially produced and off-the-shelf services and goods to leverage the latest technologies and reduce the in-house cost of doing business.[8]

The latter two reforms became known as the Clinger-Cohen Act, aiming to implement full and open competition to fulfill government requirements, provide competitive range determinations based on the initial evaluation of proposals versus mandating a certified price for item acquisition, and develop simplified and accelerated procedures for programs under $5 million when expected offers included only commercial items.

According to a 2004 RAND report, all acquisition reform initiatives impacted testing and evaluation specifically by reducing compliance costs and commercial-like practices. These are distilled as requirements reform—operational requirements document flexibility, contractor design flexibility and configuration control via Total System Performance Responsibility, and commercial insertion via commercial-off-the-shelf and nondevelopmental items.[9]

Total System Performance Responsibility intended T&E to emulate the commercial research and development paradigm. Given customer requirements and constraints, contractors had significant control and responsibility over system design, development, and testing. The contractor had primary responsibility for DT design and execution, traditionally seen in spacecraft pre-launch testing, which includes supporting ground systems. A drawback was the unavailability of critical contractor data for government use, which would force the government to recreate and/or purchase contractor data. This responsibility strategy stressed close collaboration with government testers—especially in OT—ensuring user requirements and procedures were fully realized.[10] It led to the combined testing concept: integrating contractor and government DT and OT personnel on a single team, known as the combined test force or integrated test team.[11]

This concept is now known as integrated test. Departing from contractor DT procedurally separated from government OT, IT seeks to combine DT/OT teams to ensure collaboration on ideas and integrate processes from early planning through completion of all major test activities. Benefits include eliminating redundant test activities, early issue resolution, and improved programmatic communication.

Since 2004, several government entities have offered their own IT definitions. For example, the *Integrated T&E Continuum*—as proposed in 2010 by then Director of

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7. Michael O'Connell, "Federal Acquisition Streamlining Act (1994)," Federal News Network, 2012, https://federalnewsnetwork.com/; and Defense Acquisition University, Acquipedia, s.v. "Clinger-Cohen Act (CCA)," 2022, https://www.dau.edu/.

8. O'Connell.

9. Bernard Fox et al., *Test and Evaluation Trends and Costs for Aircraft and Guided Weapons* (Santa Monica, CA: RAND Corporation, 2004).

10. Fox et al.

11. Fox et al.

Developmental Test and Evaluation Edward Greer—built upon the Office of the Secretary of Defense's (OSD) IT definition. Under this definition, IT must be an integral part of development and acquisition; efforts or resources between contractor and government DT should not be duplicated—that is, they should be enabled through communication and open sharing of data and knowledge; DT must integrate and flow into OT throughout the acquisitions cycle, as distinct phases progress; and capabilities should be consolidated to ensure sound T&E.[12]

IT facilitates continuous learning and collaboration of knowledge affecting system requirements, development, and performance. Its application across the acquisition life cycle was widely understood and accepted; however, progress was slow due to increased implementation costs; lack of "an interoperable digital engineering environment; interoperability of tooling; and a unified data strategy to support complete end-to-end knowledge and data sharing throughout the T&E phases and acquisition lifecycle."[13]

The current IT definition has been criticized because it omits an emphasis on the criticality of information and data throughout the life cycle.[14] This definition of IT was to respect independence, but it has become an obstacle, especially in space with respect to duplication of effort and/or paying for data. Authoritative sources show inconsistent definitions, challenging effective IT practice and implementation.

Following similar efforts, this article uses a democratic approach—where different sources are analyzed to identify and extract common themes and concepts—to consolidate a definition.[15] One scholar argues language is the "accepted method of human communication" to foster understanding. A precise use of language is preferred because it stresses accurately using words to achieve consensus.[16] Table 1 analyzes authoritative definitions of IT and demonstrates how the democratic approach works. Column headers show the concepts most identified in analyses. These concepts include unified team, involved team—an entire team involved at all acquisition stages—and data-sharing.

12. Edward R. Greer, "Developmental Test and Evaluation Is Back," *International Test and Evaluation Association* [ITEA] *Journal* 31 (2010), https://apps.dtic.mil/; and Charles E. McQueary and James I. Finley, Office of the Secretary of Defense, Memorandum for Component Acquisition Executives, Subject: Definition of Integrated Testing, April 25, 2008, https://www.dote.osd.mil/.

13. Laura Freeman, Geoffrey Kerr, and Jeremy Werner, "Positioning Test and Evaluation for the Digital Paradigm Building Blocks for the DE Transformation," *Journal of Test & Evaluation* 44, no. 2 (2023).

14. Stephen Tullino, interview with Dr. Andrew Freeborn, United States Air Force Test Pilot School Space Test Fundamentals Course Director, Edwards AFB, CA, May 4, 2023; and Freeman, Kerr, and Werner.

15. Jeremy R. Geiger, "Agility Measurement for Large Organizations" (PhD dissertation, Air Force Institute of Technology, September 2020), 7, https://scholar.afit.edu/; and Erin T. Ryan, David R. Jacques, and John M. Colombi, "An Ontological Framework for Clarifying Flexibility-Related Terminology via Literature Survey," *Systems Engineering* 16, no. 1 (2012), https://doi.org/.

16. Ryan, Jacques, and Colombi.

**Table 1. Summary of integrated test definitions**

| Source | Definition | Unified | Involved | Data |
|---|---|---|---|---|
| OSD Guidance Memorandum (2008) | "collaborative planning and collaborative execution . . . provide shared data . . . by all stakeholders"[17] | – | X | X |
| DoDI 5000.89 *Test and Evaluation* (2020) | "capitalizes on the idea that test events can . . . provide data for . . . evaluations."[18] | – | – | X |
| *Director, Operational Test and Evaluation (DOT&E) Test and Evaluation Master Plan (TEMP) Guidebook* vers. 3.1 (2017) | "Developmental Test incorporates characteristics of Operational Testing . . . or the data from Developmental Testing is accepted as adequate for the operational evaluation"[19] | – | – | X |
| *Test and Evaluation Enterprise Guidebook* (2022) | "merge the primary test stakeholders . . . into one unified test team . . . data sharing among all . . . utilizing all test events . . . in the program to achieve CT, DT, and OT objectives in a collaborative fashion to the maximum extent possible"[20] | X | X | X |
| DAFI 99-103 *Capabilities-Based Test and Evaluation* (2022) | "collaborative planning and execution of test phases and events to provide shared data . . . by all [DT & OT] stakeholders"[21] | – | X | X |
| DAFMAN 63-119 *Mission-Oriented Test Readiness Certification* (2021) | "collaborative planning and execution of test phases . . . to provide shared data . . . by all [DT & OT] stakeholders"[22] | – | X | X |
| SECNAV Instruction 5000.2G *Department of the Navy Implementation of the Defense Acquisition System and the Adaptive Acquisition Framework* (2022) | "Programs should . . . allow the DT and OT communities to gather needed information in the proper environment/conditions as early as possible . . . to inform programs . . . potentially reducing the scope of dedicated OT events. . . . The goal of an integrated testing event is to ensure that the collected data will be usable for DT and OT."[23] | – | X | X |

17. McQueary and Finley, Memorandum.

18. Office of the Under Secretary of Defense for Research and Engineering, and Office of the Director, Operational Test and Evaluation (DOT&E), *Test and Evaluation*, Department of Defense (DoD) Instruction 5000.89 (Washington DC: US DoD, 2020), 38, https://www.dote.osd.mil/.

19. J. Michael Gilmore, *DOT&E Test and Evaluation Master Plan (TEMP) Guidebook*, vers. 3.1 (Washington, DC: Office of the Secretary of Defense, January 9, 2017), 101, https://www.dote.osd.mil/.

20. Heidi Shyu and Nickolas H. Guertin, *Test and Evaluation Enterprise Guidebook* (Washington, DC: Under Secretary of Defense for Research and Engineering, and DOT&E, 2022), 6–7, https://www.test-evaluation.osd.mil/.

21. *Capabilities-Based Test and Evaluation*, Department of the Air Force (DAF) Instruction 99-103, DoDI 5000.89 (Washington, DC: DAF, November 9, 2021, corrective actions applied on March 15, 2022), 37, https://static.e-publishing.af.mil/production/.

22. *Mission-Oriented Test Readiness Certification*, DAF Manual 63-119 (Washington, DC: DAF, April 15, 2021), 35, https://static.e-publishing.af.mil/.

23. Carlos del Toro, *Department of the Navy Implementation of the Defense Acquisition System and the Adaptive Acquisition Framework*, Secretary of the Navy (SECNAV) Instruction 5000.2G (Washington, DC: Department of the Navy, 2022), 23, https://www.secnav.navy.mil/.

| Source | Definition | Unified | Involved | Data |
|---|---|---|---|---|
| *Space Test Enterprise Vision* (2022) | "Integration of effort across the spectrum of test activities . . . fosters early operational input into system development, while providing the developer with greater insight into the intended employment of the system."[24] | – | X | X |
| *USSF/TE Space Test Enterprise Brief* (2022) | "A collaborative, tailorable, and responsive testing approach to provide shared data for independent evaluation of system performance, effectiveness, suitability, sustainability, and survivability."[25] | X | – | X |
| USAF Arnold Engineering Development Center (2004) | "integration of modeling tools, including computations and engineering methods, in direct support of ground and flight tests"[26] | – | – | X |
| *Delta 12 Test Guidebook* | "IT combines DT and OT events to achieve greater efficiency, reduce cost, and/or accelerate . . . without compromising . . . objectives . . . Integrated Testing requires the collaborative planning and execution . . . to provide shared data in support of . . . all stakeholders. Whenever feasible, T&E campaigns will be conducted in an integrated fashion to permit all stakeholders to use data in support of their respective functions . . . early engagement with program offices and staff, test teams can ensure that system requirements are testable and T&E requirements are meaningful. IT enables early identification of system design issues and guides the system development"[27] | X | X | X |
| *Air Force Test and Evaluation Guide* (2019) | "Integrated Testing in operationally representative environments is the best method to understand performance of complex systems. Programs can accelerate learning . . . by conducting early mission-focused testing in relevant environments utilizing . . . the most stressful combinations or most likely use cases. This strategy can also expose potential operational issues early . . . and [reduce] time-consuming delay[s] towards the end of a program's development."[28] | – | X | X |
| RAND Corporation's *Test and Evaluation Trends and Costs for Aircraft and Guided Weapons* (2004) | "integration of . . . personnel on a single test team . . . [who] are involved from the early planning stages through . . . completion of all major test activities . . . early involvement of OT personnel in DT saved both costs and schedule"[29] | X | X | X |
| TOTAL (Out of 13) | | 4 | 9 | 13 |

Table 1 reveals the different definitions' intended contexts and the extent to which they represent a concept of an operationally unified team, an involved team, and data

24. *Space Test Enterprise Vision*, 7.
25. *USSF Space Test Enterprise Vision Brief* (Washington, DC: Headquarters, USSF, September 2022), 9.
26. Marcus L. Skelley, Tommie F. Langham, and William L. Peters, "Integrated Test and Evaluation for the 21st Century," 3, (paper, USAF Developmental Test and Evaluation Summit, Woodland Hills, CA, November 16–18, 2004), https://doi.org/.
27. *Delta 12 Test Guidebook (Working Copy)* (Peterson SFB, CO: Space Delta 12, 2021), appendix A.
28. *Air Force Test and Evaluation Guide Combined v. 2* (Washington, DC: USAF Test & Evaluation, September 24, 2020), 52, https://www.dau.edu/.
29. Fox et al., *Test and Evaluation Trends*, 46.

sharing throughout the test campaign. Four definitions included a unified team, nine included an involved team, and all 13 included data sharing. The terms *unified* and *involved* could be consolidated into the term *collaborative*, more accurately reflecting OSD verbiage. Using this verbiage, 10 definitions would include collaborative. These yield the following proposed definition:

> Integrated test is the streamlining and consolidation of system test activities and datapoints via collaborative planning, collaboration, and support among government and contractor agencies throughout the entire acquisitions cycle. Its objective is to verify that the system meets specifications and is validated to use cases to meet mission needs. This includes assessing combat capabilities and integration within the Joint warfighting construct. Shared data from iterative test activities are leveraged to gain the following advantages: reduce waste and risk, improve system design and performance, and increase communication among program and test management teams.

Interpretation error risks are reduced by evaluating each definition within its original context. For example, some sources define IT through lessons learned and best practices.[30] With this synthesized IT definition, this method is repeated for DT and OT.

## Developmental Test for Space Systems

Per DoD Instruction (DoDI) 5000.89, *Test and Evaluation*, developmental test informs decisionmakers, characterizes and troubleshoots system designs, matures technology via risk reduction, and prepares for OT.[31] Experts from the US Air Force Arnold Engineering Development Center add, "Along with flight testing, the ultimate goal of [DT] is to produce a complete picture of an optimized flight vehicle."[32] A RAND report further scopes this where "DT is performed at the part, subsystem, or full system level to prove design validity or reliability, materials used, etc. . . . [and] results are used to modify the system design to ensure that it meets the design parameters and system specifications."[33]

DT ensures developing technology and systems meet key performance parameters; the program office ensures this via increasing technology readiness levels (TRLs) from TRL 4 to TRL 7, known as the "Valley of Death."[34] Space Systems Command is the Space Force program office and organization tasked with DT by the *Space Test Enterprise Vision*. In 2017, Space Systems Command's chief scientist noted DT was "focused on meeting

30. Geiger, "Agility Measurement."
31. DODI 5000.89; and DAFI 99-103.
32. Skelley, Langham, and Peters, "Integrated Test and Evaluation," 11.
33. Fox et al., *Test and Evaluation Trends*, 13.
34. Elozor Plotke, Peter C. Lai, and Roberta M. Ewart, "Using Small Satellites to Construct an In-Space Test Platform for Risk Reduction," AIAA SciTech 2023 Forum, National Harbor, MD, January 23–27, 2023, https://doi.org/; and Marshall Smith et al., "Free-Flying StarLabs as Platforms for InSpace Developmental Test," AIAA SciTech Forum 2022, San Diego, CA, January 3–7, 2022, https://doi.org/.

detailed technical specifications . . . normally conducted with the contractor" and emphasized that such testing was traditionally designed to evaluate a system prior to a threat's presence via reliability, availability, and maintainability.[35]

Though well defined, there is much debate on what developmental test means for assets deployed in space versus air domains. As done with IT, the democratic approach enables the identification of what DT means for space systems by extracting key aspects via nine distinct definitions stipulated by 11 authoritative sources, with some duplicating others:

- DoD Instruction 5000.89;
- *Capabilities-Based Test and Evaluation*, Department of the Air Force (DAF) Instruction 99-103;
- *Test and Evaluation Policy*, Army Regulation 73-1;[36]
- *Implementation of the Defense Acquisition System and the Adaptive Acquisition Framework,* Secretary of the Navy Instruction 5000.2G;
- *Test and Evaluation Enterprise Guidebook*;
- *Mission-Oriented Test Readiness Certification,* DAF Manual 63-119*;*
- *Air Force Test and Evaluation Guide;*
- *Delta 12 Test Guidebook;*
- *Combined SMC T&E Guidebook* (2019);[37]
- Ewart's "SPACE Cyber Test and Evaluation Strategies for Space Enterprise Vision";
- RAND Corporation's *Test and Evaluation Trends and Costs for Aircraft and Guided Weapons* (2004).

From these, common attributes consistently emerge, listed in order of frequency: evaluate design, technical readiness, programmatic readiness, characterize systems, OT readiness, relevant environment capability, and finally, contractor involvement. Further, half of the documents do not mention "relevant environment capability" and "contractor involvement." Contractors perform most DT for space assets; there are some DAF units that conduct DT.[38]

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35. Roberta M. Ewart, "SPACE Cyber Test and Evaluation Strategies for Space Enterprise Vision," AIAA SPACE and Astronautics Forum and Exposition, September 12–14, 2017, https://doi.org/.

36. *Test and Evaluation Policy*, Army Regulation 73-1 (Washington, DC: Headquarters, Department of the Army, June 8, 2018), https://armypubs.army.mil/.

37. Engineering Directorate – Test & Evaluation Branch, *Test & Evaluation Guidebook – Combined Guidebook* (Los Angeles AFB, CA: Space and Missile Systems Center, 2019), 33.

38. Committee on Armed Services, National Defense Authorization Act for Fiscal Year 2013, "Air Force Space Developmental Test and Evaluation," S. Rep. 112-173, 59, https://www.congress.gov/.

A 2004 RAND report on T&E trends for aircraft and weapons noted the contractor conducted representative environmental/design tests as part of DT—including, but not limited to, modelling and simulation, wind tunnel tests, static article tests, avionics integration tests, special test articles, ground tests, armament/weapon delivery integration tests, and system test requirements and planning.[39]

These activities noted by RAND provide a comparable baseline to identify the essence of spacecraft DT, specifically contractor-run environmental and functional tests at unit, subsystem, and integrated levels. The Aerospace Corporation's *Space Vehicle T&E Handbook* notes tests accomplished by the contractor for a mission at the unit, subsystem, and integrated system levels typically include acoustic, vibration, shock, thermal vacuum, thermal cycling, and electromagnetic interference/charge—which evaluate the system's capability of surviving the harsh launch and space weather environments.[40]

A common methodology is iterative verification and validation (V&V) of units/subsystems/systems via "in-the-loop" means where a system is initially modelled algorithmically (algorithm-in-the loop), digitally emulated using its intended software (software-in-the-loop, SIL), and using hardware in a test stand to verify interfaces and controllability (hardware-in-the-loop, HIL).[41] Hardware-in-the-loop testing is used in the V&V of unit, subsystem, and preliminary integrated system testing. Traditionally, in spacecraft testing, the final iteration of tests can be and often are considered OT, as they are the final gamut of ground tests conducted before the spacecraft is declared cleared for launch and operations.

Given these analyses, the proposed distilled definition for space DT is:

> Developmental test and evaluation verifies that the system meets specified programmatic and technical requirements and specifications via the assessment and characterization of a system's technical performance, reliability, and maintainability. Contractors and government personnel iteratively conduct DT tests to ensure the system is technologically mature, with the technical readiness for operational testing—whether on the ground or in space. DT data feedback is shared to improve system design and performance, and to inform all involved program and test management teams.
>
> In space systems, DT is achieved through modelling and simulation activities and environmental, safety, and functional—hardware and software in-the-loop—testing at component, subsystem, and when necessary, system levels.

39. Fox et al., *Test and Evaluation Trends*.

40. National Systems Group, *Space Vehicle Test and Evaluation Handbook*, ed. J. D. White, G. A. Larsen, and D. W. Hanifen, 2nd ed. (El Segundo, CA: Aerospace Corporation, 2012).

41. Jens Eickhoff, *Simulating Spacecraft Systems* (Heidelberg, Germany: Springer, 2009), https://doi.org/.

## *Operational Test for Space Systems*

Unlike DT, operational test is explicitly defined by law:

> The field test, under realistic combat conditions, of any item of (or key component of) weapons, equipment, or munitions for the purpose of determining the effectiveness and suitability of the weapons, equipment, or munitions for use in combat by typical military users; and the evaluation of the results of such test.[42]

Operational test is not a series of mandatory, independent operator tests, or an inspection or duplication of DT. Developmental test stresses specifications to identify engineering and design deficiencies where designers, contractors, and scientists evaluate the system under test in controlled, often ideal, conditions. Operational test is more focused on user/operator needs where the system under test is evaluated in stressed and operationally realistic scenarios, typically by the operating command's personnel with normal operations and maintenance skills.[43] This type of test is legally straightforward, but its nuances still must be determined to better comprehend what OT is meant for spacecraft.

Again, elements of OT from the same authoritative sources as DT are extracted via the democratic approach, and the following common themes emerge repeatedly, in order of frequency: realistic operations conditions, effectiveness, suitability, tactics, techniques, and procedures development, threat survivability/resiliency, and programmatic readiness.

Testing and evaluation are crucial to ensure a system is programmatically ready to be operationally fielded. For space systems, OT—especially for threat survivability/resiliency—has been challenging. In 1981, the since-renamed Air Force Operational Test and Evaluation Center noted major space systems need to undergo "purposeful and significant" OT.[44] The long space system design and development timelines require OT's impact be felt early in the acquisitions cycle to influence final design and production. In traditional acquisitions, OT occurs before the production or major investment decisions, while most investments for space systems occur early, often without a major production decision.

One study noted this was still problematic in 2008, where space OT agencies tested via a model designed for large-scale production systems not appropriate for space testing.[45] Traditional programs have low expenditures in research and development compared to production and system operations, while space systems experience the opposite. Operational tests still must represent an assessment of the actual operational space system since such tests require an environment as realistic as possible, typically done via (1) data analyses of DT events, (2) a test in representative environments, or (3) a test in space.

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42. 10 U.S.C. § 139 (2011).

43. Patricia Sanders, "Challenge for Today: Operational Test and Evaluation of Space Systems," 1st Flight Test Conference, Las Vegas, NV, November 11–13, 1981, https://doi.org/.

44. Sanders.

45. Stephen T. Sargeant and Suzanne M. Beers, "AFOTEC's Space Test Initiative: Transforming Operational Testing and Evaluation of Space System Capabilities," *ITEA Journal* 1, no. 29 (2008), https://apps.dtic.mil/.

Operational test objectives using DT data are met through analyzing procedural data, factory/lab tests, ground processing, and flight operations/data. These test measures are often injected into DT events to fulfill OT objectives. Objectives trace mission needs, operational requirements, system specifications, previous test results and experiences, and the Test and Evaluation Master Plan.[46]

The Global Positioning System and Defense Support Program missions conduct this process via independent evaluation teams, applying OT objectives to contractor testing and DT data. Launch range compatibility testing does this during satellite-booster mating and OT test measures, and scenarios are inserted into DT checkout/compatibility tests, yielding operational impact assessments.[47] These are specific examples of spacecraft IT because the spacecraft's unique exposure to risks—due to the harsh environments of launch, zero gravity, extreme temperatures, and orbital maneuvering—dictate that testing activities and data points be integrated as much as possible. Data can also be collected from similar space vehicle subsystems' reliability statistics.

Satellites are normally declared operational after successful launch and early operations (LEOPS) checkouts and after stably operating for a determined time. Such operations are the most critical due to the high-risk launch environment and the full commissioning of the spacecraft.[48] In 2008, the Air Force Operational Test and Evaluation Center noted OT of space systems still had occurred after launch and ground stations were fielded, resulting in the inability to provide timely and independent OT data to decisionmakers. This compounded the problem posed by the fact that, as noted above, space system investments and decisions occurred early in the program, often without OT data.[49]

Flight environment OT defining the "flight/performance envelope" is difficult because it requires excessive commands and mandates straining a system's redundant capabilities, which are programmatically considered "high risk endeavors."[50] On-orbit OT is difficult to discreetly conduct out of the view of adversaries and poses risks to military missions. This necessitates modeling and simulation (M&S), as well as leveraging OT in other ways during DT or additional on-ground operational testing. Because of this, LEOPS deployments, telemetry monitoring, and checkouts are currently the pinnacle events of space OT.

Space Delta 12 is the Space Training and Readiness Command (STARCOM) organization responsible for US Space Force OT. The space delta executes space system OT in operational scenarios, which help define a spacecraft's performance envelope—akin to aircraft methods—when conducting operations in nominal, natural and hostile, and intentional

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46. Sargeant and Beers; and Sanders, "Challenge."
47. Sargeant and Beers.
48. James R. Wertz, David F. Everett, and Jeffery J. Puschell, eds., *Space Mission Engineering - The New SMAD* (Hawthorne, CA: Microcosm Press, 2015).
49. Sargeant and Beers, "AFOTEC's Space Test Initiative."
50. Sanders, "Challenge."

threat conditions.[51] Traditionally, testing mostly evaluates the spacecraft's hardiness against environmental and launch stresses. Evaluating a spacecraft in hostile environments requires further tests against various threats. In 1981, the Air Force Test and Evaluation Center noted that a realistic testing environment can only be partially attained through simulating conditions to test subsystems, providing limited scope in establishing confidence.[52]

Given this, spacecraft OT can be distilled into the following definition:

> Operational test and evaluation focuses on validating whether the system meets operational user and mission needs, and whether it can be employed in operational use cases—both nominal and contested scenarios—in the intended way. It does this by evaluating a system's effectiveness, suitability, and survivability in realistic operational conditions.
>
> In spacecraft, OT is typically conducted through (sub)system verification on non-developmental test environmental tests—thermal, radioactive, etc.—verification of DT data, concurrent execution of OT data points during contractor DT events, and on-orbit tests during early and full operations.

## *Integrated Test for Space Systems*

Space system T&E space environment difficulties forced the space community to conduct rudimentary IT via concurrently executing OT datapoints during contractor DT events—that is, incorporating OT characteristics into DT events—and verifying and accepting DT data for operational evaluation. This correlates with the *Director, Operational Test and Evaluation (DOT&E) Test and Evaluation Master Plan (TEMP) Guidebook* as follows.[53]

Characterizing and measuring capacities not reliant on test conditions can be satisfied via DT and can be included in OT evaluations. Testing must use engineering development units and/or models and testing production representatives to measure performance and characterize (sub)system performance as well as hardware-in-the-loop tests. Testing must also use environmental test data to collect OT datapoints as well as historical data and testing of subsystems in thermal, electromagnetic, and radiation environmental tests, as mentioned before. Development test events should be conducted under sufficiently operationally realistic conditions.

In LEOPS and normal operations all space-based tests can be observed, making testing difficult. Modeling and simulation via SIL/HIL and other computer models can bridge this gap and reduce risk in small spacecraft (SmallSat) missions.

51. *Space Test Enterprise Vision*; and Stephen Tullino, interview with Colonel E. Lincoln Bonner, commander, Space Delta 12, Schriever AFB, CO, March 24, 2023.

52. Sanders, "Challenge."

53. Gilmore, *DOT&E TEMP*.

Schedule and resource limitations traditionally forced SmallSats and CubeSats—a class of nanosatellites—to be solely functionally verified through simulations.[54] These missions had low success rates, approximately 48 percent in 2010. Until 2015, 20 percent of CubeSats failed post-launch.[55] Recent missions began to use HIL techniques used in traditional satellite testing via flat satellites (FlatSats) for (sub)system V&V.

Using FlatSats for CubeSats can be considered an example of IT because many of these programs iteratively test their satellites as designs mature. This lean approach is necessary due to smaller teams, less funding, and shorter timelines.[56] FlatSats are powerful because they enable rapid flaw identification and correction in design, interfacing, and most nonmechanical issues. FlatSats allow early functional test development, enabling early identification of software and hardware design flaws, so that flight hardware testing focuses only on workmanship.

The feedback-intensive nature of FlatSats ensures the robustness of the system design and software. This is used at the Air Force Research Laboratory SmallSat Portfolio, where its satellites undergo full system V&V through four critical tests: (1) a command and execution test in which full software functionality executes each command; (2) a power characterization test which tests full power subsystem functionality, characterization, and safety limits; (3) a long-range communications verification test ensuring communication links close; and (4) a day-in-the-life test that demonstrates spacecraft critical functionality and all operational modes. This final test ensures the system performs as intended and executes the LEOPS sequence. [57]

These tests are iteratively conducted via emulator (SIL), HIL FlatSat with engineering units, FlatSat with flight units, and fully integrated spacecraft. Each instance of these tests identifies problems and informs the subsequent iteration up to the point where the LEOPS sequence during spacecraft commissioning is executed almost out of routine, in line with Test Like You Fly. Iterative in-the-loop methods qualify and characterize the system in a timely manner, while increasing design robustness and capability confidence—a powerful tool capable of crossing DT, OT, and M&S. Regarding Test Like You Fly, STARCOM is tasked with establishing a network of ranges focused on providing realistic threat-informed test and training environments known as the NSTTC.[58]

This complex focuses on four areas: service capability, Joint applicability, IT, and threat replication. These tests are supported via electromagnetic, on-orbit, cyber, digital, and multidomain command and control. The NSTTC integrates multiple venues, leveraging

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54. Sabrina Corpino and Fabrizio Stesina, "Verification of a CubeSat via Hardware-in-the-Loop Simulation," *IEEE Transactions on Aerospace and Electronic Systems* 50, no. 4 (2014), https://doi.org/.

55. João Cláudio Elsen Barcellos et al., "FlatSat Platforms for Small Satellites: A Systematic Mapping and Classification," *IEEE Journal on Miniaturization for Air and Space Systems* 4, no. 2 (2023), https://doi.org/.

56. Jared Clements et al., "Tailored Systems Engineering Processes for Low-Cost High-Risk Missions," in *Space Education and Strategic Applications* 1, no. 1 (2019), https://doi.org/.

57. Clements et al.

58. Bratton and Seballes, "Vision."

on-orbit, digital, HIL, lab, and chamber testing—supporting one another in achieving test objectives. Testing and training focus on multilevel blue-force M&S, from digital twins to exquisite capabilities; program validation via integrating DT, OT, and training; and tactics, techniques, and procedures validation. These align to the in-the-loop test approach as an effective means to marry developmental test, operational test, and modeling and simulation.

Incorporating these, the guiding IT philosophy for combat space systems has been defined as "the use of test to learn (i.e., characterize) as much about the combat capabilities of space systems as practical at all times, regardless of system maturity."[59] The integrated test framework (fig. 2) elaborates on this.

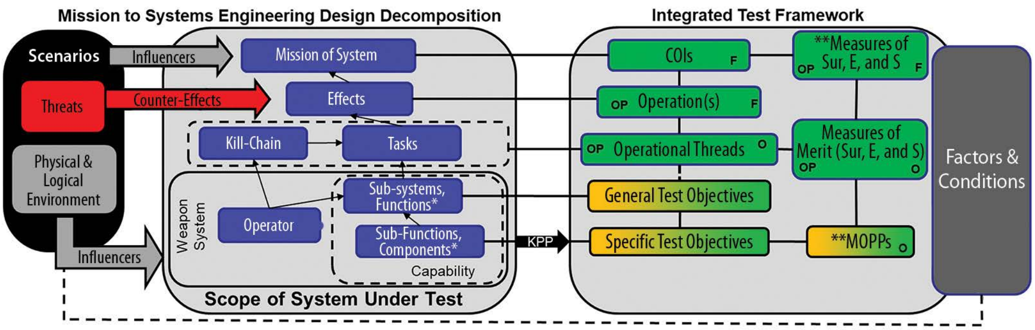


**Figure 2. STARCOM Delta 12/4th Test and Evaluation Squadron mission-to-systems engineering and IT framework**[60]

Guided by survivability, susceptibility, vulnerability, and recoverability, the IT framework decomposes mission needs to flexibly meet objectives with respect to factors and conditions. The IT framework introduces one new concept, *measures of merit*. Delta 12 posits these to bridge the gap between mission and functionality—in between measures of effectiveness and performance. These are focal points of analysis to describe system performance of a task, or an aspect related to how the mission was executed. This is an additional tier proposed by Delta 12 and permitted under STARCOM guidance.

The IT framework ties to systems engineering design (fig. 2), as the framework translates the engineering design into characterizable (nonrequirements) and evaluable (requirements) aspects against operational scenarios determining how well the system under test performs its mission in its intended way. This includes any new systems or aspects, operational tactics, tasks or kill chains for evaluation, and enhancements to the test framework and systems engineering designs.

59. E. Lincoln Bonner, "Space Delta 12 Update and Integrated Test Force (ITF) Construct" (presentation, 2023 Space Test and Evaluation Summit, Colorado Springs, CO, 2023).

60. Kenneth H. Carpenter III, *Test Combat Framework Guide* (Schriever SFB, CO: STARCOM Delta 12, 4th Test and Evaluation Squadron, 2023).

This framework manifests in the Integrated Survivability Assessment as inspired by the *DOT&E TEMP Guidebook*, where operational scenarios guide the design systems' DT so that test data can naturally inform OT parameters.[61] This can be adapted to show how IT could be carried out on a system (table 2).

**Table 2. Adaptation of integrated assessment paradigm to space system T&E**

| | DT | M&S | OT / Live Fire |
|---|---|---|---|
| Mission Planning System | X (hardware-in-the-loop [HIL]) | X (algorithm-in-the-loop [AIL], software-in-the-loop [SIL], HIL) | X (HIL, Spacecraft) |
| TTPs | X (HIL) | X (AIL, SIL, HIL) | X (HIL, Spacecraft) |
| Spacecraft Signatures (RF, IR, Visual) | X (Unit Testing, Environmental) | X (Representative Model) | – |
| Spacecraft Performance Envelope | X (HIL, Environmental) | – | – |
| Software | X (AIL, SIL, HIL, Spacecraft) | X (AIL, SIL, HIL) | – |
| Sensors Envelopes | X (Unit Testing w/ HIL, Environmental) | – | – |
| Subsystems Envelopes | X (Unit Testing w/ HIL, Environmental) | – | – |
| Threat Tolerance (Vulnerability) | – | X (Representative Model) | X (Environmental & On-Orbit) |

Test objectives can be arranged via what is traditionally DT, OT, and M&S, complementing and improving upon each other and/or enabling a more holistic yet efficient approach, especially through in-the-loop means. Model V&V is iteratively achieved—data being checked against itself and against specifications—and to intended use cases, using realistic operational data where possible.

## Conclusion

Existing developmental test, operational test, and integrated test terminology suffer from ambiguities and inconsistencies, leaving testers to guess the scope of these test activities and thus creating challenges in meeting the spirit and intent of the *Space Test Enterprise Vision*.[62] To ensure US Space Force field commands consistently adhere to this

61. Tullino, interview with Bonner.
62. *Space Test Enterprise Vision*.

vision, an established baseline is necessary to understand what DT, OT, and IT mean, and what they could look like.

The proposed definitions thoroughly and inclusively fuse views from key sources to provide a basis of clarification for establishing authoritative definitions. The analyses are intended to serve as a catalyst for helping the space community engage in further discussion, alignment, and refinement, facilitating the foundation for an integrated test architecture, specifically the National Space Training and Testing Complex and the operational test and training infrastructure.

# From Cars to People

## Advancing Installation Design

Louis J. Zib III
Christopher M. Chini

While the US Air Force stresses reducing facility life-cycle costs in its design of air bases, supporting infrastructure including roads and utility lines is not figured into cost calculations. As such, the Air Force's current base design maximizes passive protections against outmoded attacks, often to the detriment of supporting infrastructure cost. By exploring how air base design will be altered when supporting infrastructure considerations are paired with updated adversarial attack scenarios, this study proposes a modernized base design that is more cost efficient and more effective at mitigating adversary attacks.

Currently, US Air Force bases are designed to prioritize cars and their use, which is intended to mitigate invasive and noninvasive near-strength adversary attacks. The car-centric use of space between facilities, redundant infrastructure, and low-density buildings is meant to play a role in reducing the effect of such attacks. Yet such a design is based on attack strategies from the World War II and Cold War eras, and the relevance of such strategies to today's environment remains dubious.[1]

Technologies and advancements in homeland defense systems—such as radar-based tracking and intercepting capabilities—reduce the likelihood of such adversarial attacks, limiting the passive effectiveness of car-centric base design in decreasing disruption to operational throughput. In addition, the life-cycle costs of supporting infrastructure inherent to such a car-centric design have not been analyzed. These life-cycle costs are the construction, operation, maintenance, and demolition costs associated with assets that need to be built and maintained for a facility to function for its intended usage over its lifespan; these assets include roads and electrical, waste, water, gas, and communication lines. Today's Air Force faces the challenge of maintaining aging and outdated supporting infrastructure with increasing maintenance costs.[2]

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1. Tod D. Wolters et al., *U.S. Air Force Infrastructure Investment Strategy (I2S)* (Washington, DC: Headquarters, US Air Force, 2019), https://www.af.mil/.

2. Joel A. Sloan et al., "Infrastructure Truths for Air, Space, and Cyberspace," *Air & Space Power Journal* 35, no. 1 (2021), https://www.airuniversity.af.edu/.

Considerable research and effort have been focused on reducing maintenance costs following consolidation guidance set forth in the US government-based Whole Building Design Guide, corresponding installation facilities standards, and other such principles for government and industry professionals.[3] Yet few studies have explored the underlying design criteria the Air Force should utilize when developing the installation of the future and the supporting infrastructure costs and needs. Given the technological advancements of the war machine coupled with the decreasing probability—and usage—of conventional warfare doctrine projected by US near-strength adversaries, the Air Force must adapt a sustainable base model most suited to current and future threats.

Air Force base design centers on four key principles: (1) incrementally increase barriers of access to critical assets, (2) provide resilient protection of the base against adversarial attacks, (3) consolidate the land requirements for the operational and support areas, and (4) reduce the life-cycle costs of facilities.

While the last principle stresses reducing the life-cycle costs for facilities and their individual utility input, support infrastructure is not included in life-cycle cost calculations. In fact, the current car-centric design maximizes the key principles for facilities to the detriment of supporting infrastructure cost, placing the facility at the focal point for operational effort and neglecting the importance of supporting infrastructure. Including life-cycle costs for this infrastructure within the fourth key principle would change the optics that drive base design, allowing planners to make more informed strategic, economic, and holistic decisions regarding base design and to determine more effective alternatives to a car-centric design.

In examining the strengths and costs of the current Air Force base design, this article offers an alternative design that includes life-cycle cost analysis for the supporting infrastructure and sustainable benefits of a redesign. While there are challenges associated with a redesign, the Air Force must move forward with such efforts to meet today's and tomorrow's base attack scenarios while maximizing holistic base sustainability gains.

## Maintaining Supporting Infrastructure

Air Force infrastructure—facilities and supporting infrastructure—is an integral component of base operations.[4] The life-cycle costs of supporting infrastructure are measured by the cost per linear unit.[5] The funding requirements to maintain, repair, and modernize the existing infrastructure are largely based on a percentage amount set aside

3. "Whole Building Design Guide," WBDG (website), October 8, 2021, https://wbdg.org/.

4. Sloan et al., "Infrastructure Truths"; and Wolters et al., *Infrastructure Investment Strategy*.

5. "Whole Building Design Guide"; Rajkumar Roy, "Cost Engineering: Why, What and How?," in *Decision Engineering Report Series,* ed. Rajkumar Roy and Clive Kerr (Cranfield, UK: Cranfield University, 2003), https://dspace.lib.cranfield.ac.uk/; Anghel Patrascu, *Construction Cost Engineering Handbook* (Boca Raton, FL: CRC Press, 1988); and "Materials Prices," ARTBA [American Road & Transportation Builders Association], October 8, 2021, https://www.artba.org/.

for maintenance.[6] Each base then competes centrally to fund infrastructure most in need of repairs. A metric and associated formula are utilized to rank the projects against one another. They both normalize the projects for direct competition but do not account for life-cycle costs of attached supporting infrastructure.

Historically, organizations spend approximately 3 to 9 percent of a facility's total replacement value on its maintenance, with world-class businesses settling on the 2.5 to 3.5 percent value range, using an optimized facility management plan.[7] Based on these statistics, the Air Force should spend at least $7.89 billion on base maintenance for its infrastructure and facilities. Yet the Air Force has committed to just $5.26 billion to maintain its existing infrastructure.[8] It should also be noted that the Air Force has been below the 2 to 9 percent maintenance amount in prior years.[9] In short, the Air Force currently attempts to maintain its vast infrastructure with an inadequate budget, which results in infrastructure that continues to degrade over time. Furthermore, the Air Force has a $33-billion backlog of deferred maintenance and recapitalization, which is projected to triple in the next 30 years. The Air Force will continue to see a deficit unless maintenance spending levels increase or costs significantly decrease.[10]

The Air Force has made progress in including these costs within new construction and major renovations, using sustainability programs such as Leadership in Energy and Environmental Design, the Building Research Establishment Environmental Assessment Method, and Green Globe.[11] While these certifications focus on increasing the efficiency gained from the use of the existing supporting infrastructure supply, they do not address the placement—holistic integration to the supporting infrastructure—or trade-offs for site location to the existing supporting infrastructure.

From the Air Force Comprehensive Asset Management Plan for fiscal year 2021–25 onward, supporting infrastructure projects have no formulaic incentives or positive considerations tied to reducing its footprint. Generally, supporting infrastructure projects are at a funding disadvantage since the metric and associated formulas used to normalize projects were originally designed to compete facility projects.[12]

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6. Wolters et al., *Infrastructure Investment Strategy*; and Sloan et al., "Infrastructure Truths."

7. John S. Mitchell, *Physical Asset Management Handbook* (Houston, TX: Clarion Technical Publishers, 2002); and Brian Atkin and Adrian Brooks, *Total Facility Management* (Hoboken, NJ: John Wiley & Sons, 2021).

8. Wolters et al., *Infrastructure Investment Strategy*.

9. Brendan Maestas et al., "Defining Success in Air Force Infrastructure Asset Management through Use of the Delphi Technique," in *Engineering Assets and Public Infrastructures in the Age of Digitalization, Proceedings of the 13th World Congress on Engineering Asset Management*, ed. Jayantha P. Liyanage, Joe Amadi-Echendu, and Joseph Mathew (Cham, Switzerland: Springer Nature, 2020).

10. Wolters et al., *Infrastructure Investment Strategy*.

11. "LEED Rating System," USGBC [US Green Building Council], accessed May 28, 2024, https://www.usgbc.org/; "An Introduction to How BREEAM Works," BREEAM [Building Research Establishment Environmental Assessment Method], accessed May 28, 2024, https://breeam.com/; and "The Global Leader in Sustainable Tourism Certification," Green Globe, accessed May 25, 2024, https://www.greenglobe.com/.

12. "Civil Engineeering Playbooks: AFCAMP Business Rules," Air Force Civil Engineer Center.

Although reductions in life-cycle costs continue for facilities by increasing utility efficiencies such as upgrading lighting systems, such costs are not calculated for the supporting infrastructure. By factoring in such infrastructure life-cycle costs in the fourth key base design principle, designers would consider cost interactions between the capacities of the existing supporting infrastructure and the proposed facility, prioritizing sustainable integration. Consolidation of operational and support areas would include the supporting infrastructure system. This inclusion of life-cycle costs would allow base designers to determine alternatives to a car-centric design, such as a people-centric design.

## Car-Centric Design

Car-centric design was first introduced at the 1939 World's Fair in New York as an ideal that shifted the primary mode of transportation within a city from walking and public transit to privately owned vehicles (POVs).[13] Since that time, car-centric design continues to be the primary default for North American cities, but it is widely criticized today for its limits in terms of sustainability.[14] The hallmarks of car-centric design are roads and interactions with the urban environment centered on efficient car travel, with walking and public transit as secondary priorities. Car-centric design allowed planners to develop suburbs outside the urban center of a city.[15]

Such a design also results in long runs of roads and electrical, gas, and water utility lines to accommodate the distances between the city's urban centers and its surrounding suburbs. Applied to a military installation, from a defensive standpoint, car-centric design limits the potential efficacy of any adversary attack since the targeted area grows as the infrastructure lines between facilities increase in length. This design also comes at a cost, limiting the efficiency and sustainment—or the operation and maintenance—of the support infrastructure connecting the facilities within that area.

Without analyzing supporting infrastructure life-cycle costs, the Air Force adopted car-centric design as the key design for bases. While the Air Force's fourth principle of building design stresses reducing life-cycle costs for facilities and their individual utility input, as previously mentioned, support infrastructure is not included in life-cycle cost calculations.

The car-centric design maximizes the key principles for facilities to the detriment of supporting infrastructure cost, placing the facility as the focal point for operations. For example, maximizing the distance between facilities—one characteristic of the car-centric design—provides increasing passive barriers of access and minimizes adversarial damage to facilities, but at the cost of longer supporting infrastructure lines. As of 2021, bases

13. Paul Mason Fotsch, *Watching the Traffic Go By: Transportation and Isolation in Urban America* (Austin: University of Texas Press, 2007).

14. Charles L. Marohn Jr., *Strong Towns: A Bottom-Up Revolution to Rebuild American Prosperity* (Hoboken, NJ: John Wiley & Sons, 2019); and Fotsch.

15. Marohn; and Fotsch.

consolidated individual operational and support facilities while leaving the broader supporting infrastructure system largely the same.[16]

## Car-Centric Installations

Air Force bases have historically been built on existing airports and air fields away from city centers and highly populated areas.[17] Since World War II, the four guiding principles to Air Force base creation centered on the conservation of funds, materials, and national effort; efficiency of operation; maximum use of available facilities; and elimination of nonessentials.[18] By the Cold War, these principles involved force structure, operations, deployments, available facilities, reactivation of existing bases prior to new construction, and a life-cycle of 25 years, a time frame that all have exceeded.[19]

During World War II, an Air Force base location was selected in accordance with these principles, with the main concern being its ability to generate sorties if the base came under attack. This concern stemmed from strategies observed during that time: mass bombing runs backed by fighter escorts. The intent of such tactics was to cause the most destruction possible within an area to disrupt base operations. As such, Air Force bases were designed primarily in low population areas away from city centers to reduce damage to civilian populations.[20]

Additionally, they were designed with space in mind—for example, with the cantonment area and support areas located miles away from the operational flight lines. While dormitories were no more than two or three stories high, operational facilities were often single-story and constructed with large interior footprints.[21] Such a design advantage reduced the ability of a single bomb to halt the facility's operational effort during the war.

Facilities were also designed to be set apart from each other whenever possible. Additional space between facilities assisted in reducing the effective damage a single bomb could produce. To ensure facility operations were available even during an attack, designers planned for redundant support infrastructure for each facility. Electrical infrastructure typically followed a loop system to provide electricity from either junction to a facility if the grid was damaged. Similarly, roads were placed to access each facility from multiple approaches to maintain its logistical throughput. This redundancy assured that bombing runs would yield less efficiency against the facility and that further investments into bombers and corresponding bombs would be needed to destroy its operations.

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16. "AFCAMP Playbook."

17. Frederick J. Shaw, ed., *Locating Air Force Base Sites History's Legacy* (Washington, DC: Air Force History and Museums Program, 2004), https://www.amc.af.mil/.

18. Robert Frank Futrell, *Development of AAF Base Facilities in the United States, 1939-1945* (Manhattan, KS: Sunflower University Press, 1947).

19. Shaw, *History's Legacy*.

20. Robert Mueller, *Air Force Bases: Active Air Force Bases within the United States of America on 17 September 1982*, vol. 1 (Washington, DC: Office of Air Force History, 1989).

21. "Whole Building Design Guide"; and *Unaccompanied Housing Design Guide* (Washington, DC: Headquarters, USAF, January 2006), https://www.wbdg.org/.

Lastly, Air Force bases were developed with additional distances between the operational areas and its personnel housing and support areas to mitigate the damages from strategies, as discussed above.[22] As a result, air bases feature the airfield in the middle, surrounded by its infrastructure, reducing the effects of a bombing run on the airfield's operations.

Positioned away from the airfield, the housing area comprises low-density housing units, which provide their own security against bombing runs to the population living there. Additional off-base housing is intended to deter adversaries that have the requisite capabilities from finding any gain in bombing housing areas. For unaccompanied Airmen, dormitories are no taller than three stories, and they are often grouped in individual islands throughout the housing area. Support structures such as schools, child development centers, and other base amenities are placed in locations away from housing and the airfield. All these measures are supported by the miles of roads and electrical, gas, and water lines. An example of the current car-centric base design can be seen in figure 1.

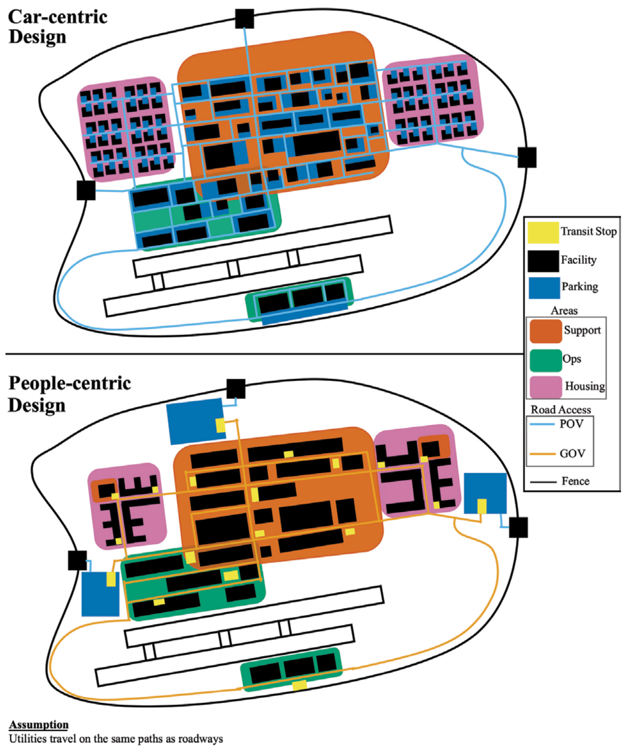


**Figure 1. An example base design created using current car-centric design and a proposed people-centric design**

22. S. Nelson Drew and Paul H. Nitze, *NSC-68 Forging the Strategy of Containment* (Darby, PA: Diane Publishing, 1994); and LeRoy A. Brothers, "Operations Analysis in the United States Air Force," *Journal of the Operations Research Society of America* 2, no. 1 (1954), https://www.jstor.org/.

With a car-centric design, the Air Force is paying for a design whose core premise is to deter effective noninvasive attacks from near-strength World War II- and Cold War-era adversary tactics. Yet since that time, the Air Force has developed homeland defense technologies and systems to counter such attacks. Base design should therefore instead focus on reducing current and future attacks while minimizing support infrastructure costs. Such a design should be driven by the inclusion of the support infrastructure sustainment costs and estimated repair costs from today's likely attack scenarios.

## Criteria for a Modernized Base Design

Today's Air Force faces threats that could not be foreseen in the 1940s, when car-centric bases were designed. The current threats to air base physical infrastructure, augmented by rapid technological advancement, differ considerably from that period.[23] The United States' defense strategy emphasizes the need to protect the homeland from state, nonstate, and transboundary threats, such as climate change and the COVID-19 pandemic.[24] The increased reliance on computer and electronic technologies has become a vulnerability that can be targeted by near-strength adversaries.[25] US reliance on electronics to send messages, monitor infrastructure, and use transportation systems can all be disrupted by an electromagnetic pulse blast. Nonstate actors have a lower barrier to access capabilities that can cause mass disruptions to defense, government, and economic infrastructure.[26] These actors can interfere with operational efforts without the limitations, consequences, or costs associated with state adversaries using conventional means of attack.

Likely threats to an Air Force base center on unconventional warfare and technologically advanced noninvasive attack strategies aimed against current operational capabilities and infrastructure.[27] These threats could impact operational capabilities by disrupting supporting infrastructure to a facility as well as target the facility directly.

Figure 2 details the likelihood of disruptive events for expeditionary base design and homeland base design. At an expeditionary base, the most likely scenario involves conventional and unconventional noninvasive attacks. Yet, the most likely disruptive events for a homeland base is unconventional noninvasive attacks and maintenance/repair of aging infrastructure. As such, the design for the two bases should give the greatest considerations to these most likely threats, respectively.

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23. James N. Mattis, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: Department of Defense [DoD], January 2018).

24. Lloyd J. Austin III, *2022 National Defense Strategy of the United States of America* (Washington, DC: DoD, October 2022), https://media.defense.gov/.

25. Mattis, *Summary*; Michale Chipley, "Cybersecurity," WBDG, last updated February 21, 2020, https://www.wbdg.org/; and Austin, *National Defense Strategy*.

26. Mattis; and Austin.

27. Mattis; Sloan et al., "Infrastructure Truths"; and Austin.

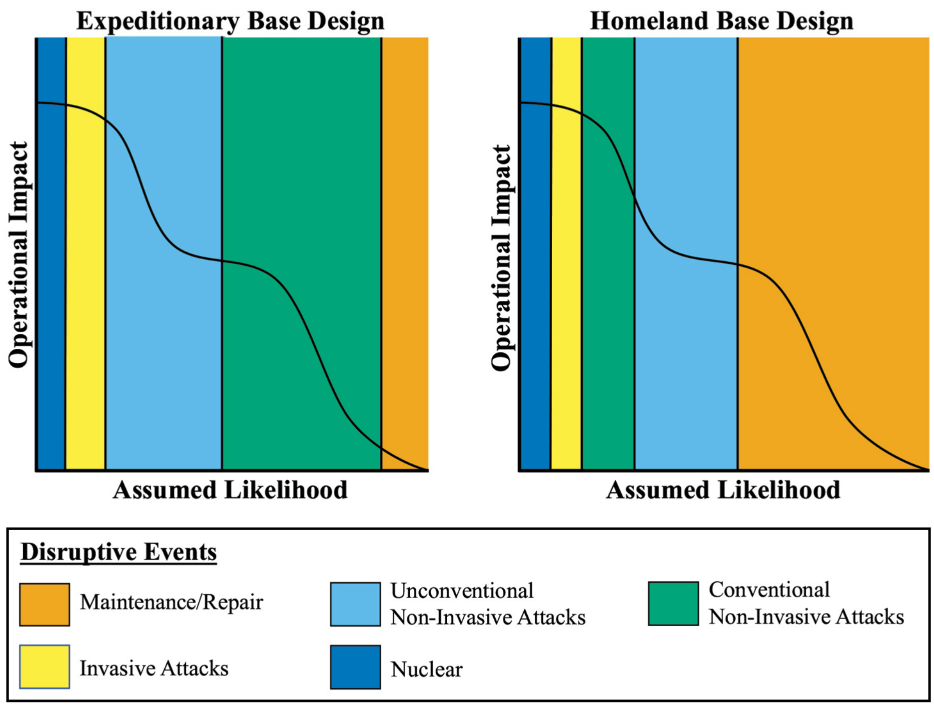


**Figure 2. Differences in assumed likelihood of disruptive events toward operational output between the expeditionary and homeland base designs**

Researchers have analyzed the resilient protection of infrastructure and have proposed several solutions to better protect facilities against conventional, nuclear, and unconventional threats.[28] For example, electromagnetic pulse shielding can be introduced to telecommunication lines and industrial control systems to protect the supporting infrastructure from unconventional warfare. Guidance and teams have been created to respond to and prevent future cyberattacks on these systems.[29]

Additional mechanical restrictions, such as locks and fencing coupled with restricted badging, can deter and delay a small insertion team from disrupting the supporting infrastructure. First responders can counter such incursions more rapidly since they can bypass the same security measure.

Consolidating land requirements would involve constructing multi-use/multilevel facilities, which can support a wide range of operational efforts. With POVs prohibited from

28. Chipley; Mattis, *Summary*; Austin, *National Defense Strategy*; and S. M. Anas and Mehtab Alam, "Comparison of Existing Empirical Equations for Blast Peak Positive Overpressure from Spherical Free Air and Hemispherical Surface Bursts," *Iranian Journal of Science and Technology, Transactions of Civil Engineering* 46, no. 2 (2022), https://doi.org/.

29. Chipley.

operational and support areas, it is possible to reduce the standoff distance between facilities.[30] Taller facilities—which could be designed to resist progressive collapse or air blasts in the event of an attack—would allow for higher density for a given square footage.[31] Coupling such facilities with reduced standoff distances between facilities would create more walkable areas, encourage mass-transit options, and promote their cross-organizational efforts.

With large standoff distances between groupings of facilities, the use of mass transit would also be able to maintain connection to all facilities while providing the benefit of the modernized base design. Government-owned vehicles (GOVs) may still be required, and a base designer should ensure that contingencies are in place should the mass transit system fail or if and when adversarial attacks hinder transportation infrastructure.

Finally, the reduction of infrastructure life-cycle costs would need to be considered during the development of modernized base design. Researchers have explored multiple methods to reduce such costs for the electric grid, water and wastewater lines, and transportation systems.[32] Collocating utility infrastructure into multi-utility tunnels allows for reduced projected labor hours necessary to access, observe, and repair utility runs.[33] Consolidating support infrastructure can also reduce its sustainment cost, restrict access, and protect the infrastructure from adversarial attacks.

Maintenance costs for support infrastructure are inherently tied to the linear amount required to support each tied-in facility. Along with increased cross-organizational communication opportunities, condensing multi-use/multilevel facilities into a smaller land area would reduce overall maintenance costs with only a marginal decrease in protection. While initial construction costs would be higher compared to current design standards, reduced sustainment costs over the life cycle of the support infrastructure will result in a lower support infrastructure life-cycle cost. This modernized base design would account for the threats of today while increasing the resiliency and robustness of the base infrastructure.

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30. Larry D. McCallister et al., *Minimum Antiterrorism Standards for Buildings*, UFC 4-010-01 (Washington, DC: DoD, December 12, 2018, Change 2, July 30, 2022), https://wbdg.org/.

31. David Stevens et al., "DoD Research and Criteria for the Design of Buildings to Resist Progressive Collapse," *Journal of Structural Engineering* 137, no. 9 (2011), https://doi.org/; Huda Helmy, Hamed Salem, and Sherif Mourad, "Progressive Collapse Assessment of Framed Reinforced Concrete Structures according to UFC Guidelines for Alternative Path Method," *Engineering Structures* 42 (2012), https://doi.org/; Robert Smilowitz, "Designing Buildings to Resist Explosive Threats," WBDG, updated September 14, 2016, https://wbdg.org/; Uwe Starossek, *Progressive Collapse of Structures*, vol. 153 (London: Thomas Telford, 2009); and Jose M. Adam et al., "Research and Practice on Progressive Collapse and Robustness of Building Structures in the 21st Century," *Engineering Structures* 173 (2018), https://doi.org/.

32. Luis Hernández-Callejo, "A Comprehensive Review of Operation and Control, Maintenance and Lifespan Management, Grid Planning and Design, and Metering in Smart Girds," *Energies* 12, no. 9 (2019): 1630, https://doi.org/; Jawwad Latif et al., "Review on Condition Monitoring Techniques for Water Pipelines," *Measurement* 193 (2022): 110895, https://doi.org/; and Shouzheng Pan et al., "Vulnerability and Resilience of Transportation Systems: A Recent Literature Review," *Physica A: Statistical Mechanics and its Applications* 581 (2021): 126235, https://doi.org/.

33. D. V. L. Hunt, D. Nash, and C. D. F. Rogers, "Sustainable Utility Placement via Multi-utility Tunnels," *Tunnelling and Underground Space Technology* 39 (2014), https://doi.org/.

## People-Centric Design

Based on the established criteria, a people-centric design would adequately satisfy the revised criteria for the modernized base design. Figure 1 exemplifies the strengths of the people-centric design.

### *Closed-Road System*

The closed-road system—eliminating POVs within the operational and support areas—permits only GOV access throughout the base, limiting individual transit to restricted locations and thus curtailing the need to have large antiterrorism standoff distances between facilities.[34] To mitigate mobility challenges for base users, policymakers could set funding guidelines and methods to allow for a government transit system—such as rapid bus transit or light rail—that could provide services in a timely and predictable manner.[35]

Base leadership could establish additional restrictions to personnel access at specific transit stops if necessary. The transit loop could also collocate the infrastructure necessary to support the operational effort of the airfield. Redundant legs to the transit loop and support infrastructure would allow for maintenance and repair of damaged infrastructure without impacting the base's operational effort. Lastly, the centralized utility backbone would inherently limit excessive runs of infrastructure and be more sustainable than the car-centric base design. Policymakers can make the funding available in the form of competitive funds solely for sustainment of support infrastructure projects. Separating out such projects, which historically are noncompetitive against facilities for sustainment funds, would benefit overall base sustainment.

While there are benefits to eliminating POVs from the base road systems, it is more difficult to determine the benefits of the people-centric design compared to the car-centric design with regard to active shooter scenarios. Methods—such as using virtual reality—to analyze the human-building interactions during active shooter scenarios are available but are outside the scope of this article.[36]

34. McCallister, *Minimum Antiterrorism Standards*.

35. David A. Hensher and Thomas F. Golob, "Bus Rapid Transit Systems; a Comparative Assessment," *Transportation* 35, no. 4 (2008), https://doi.org/; Vukan R. Vuchic, *Urban Transit Systems and Technology* (Hoboken, NJ: John Wiley & Sons, 2007); Peter A. Duerr, "Dynamic Right-Of-Way for Transit Vehicles: Integrated Modeling Approach for Optimizing Signal Control on Mixed Traffic Arterials," *Transportation Research Record* 1731, no. 1 (2000), https://doi.org/; and Lloyd Wright and Karl Fjellstrom, *Mass Transit Options, Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities*, vol. 3, 3a (Eschborn, Germany: Deutsche Gesellschaft für Technische Zusammenarbeit, 2003).

36. Runhe Zhu et al., "Infrastructure Requirements for Virtual Environments to Study Human-Building Interactions during Active Shooter Incidents," in *Computing in Civil Engineering: Proceedings of the ASCE International Conference on Computing in Civil Engineering 2019*, ed. Yong K. Cho et al. (Reston, VA: ASCE Press, 2019), https://doi.org/.

## *Closer Proximity and Consolidated Facilities*

With the inclusion of a properly designed closed-road system, facility proximity can be reduced. This reduction encourages walkability, discussed above. In addition to myriad health benefits from nonmotorized personal transit, incorporating mass transit stops encourages support agencies to consolidate around these transit nodes. Supporting agencies could better plan the most accessible locations to place grocers, retail, and restaurant amenities as walkability increases.

In a people-centric base, residents and employees could participate in base operations without needing a POV—and also avoid the associated financial strain. This would provide more morale-building opportunities, enable easier access to supporting facilities, and build community relations. Moreover, supporting facilities could be included within the housing areas, allowing for each neighborhood to develop its own unique culture.

Lastly, facility consolidation would reduce the individual strain of security systems and restricted access to facilities as multiple entities benefit from the shared use of such systems. While design and construction of multifunctional facilities are overall more expensive, sustainment costs—which account for the largest cost that a facility experiences throughout its life cycle—would be reduced.[37] The more functions that a facility can support, the more efficient the operation and sustainment costs per function.

## *Resiliency against Disruptive Events*

The envisioned people-centric design incorporates new technologies and designs that retain attack protection. Planners would consider the most likely adversarial attacks associated with a specific base—in-garrison or contingent—and employ available systems or platforms to reduce the likelihood of a successful disruptive event.

If a conventional attack does occur, the base commander would still be able to generate sorties due to GOV traffic being a viable option for the operational area—with larger spacing between grouped facilities reducing the effective operational disruption associated with conventional bombing strategies. Additionally, damage to the utility infrastructure backbone would have less of an impact due to the lines collocated with the redundant legs to the transit loop.

Air-blast resistant and progressive collapse structures would allow personnel the time needed to evacuate a targeted facility. As a last resort, contingent supporting infrastructure could be utilized until the backbone is repaired and operational. Walkability would allow base operations to continue if the road infrastructure is disrupted by craters or damaged roadways, for example. Couriers could be established if all other communication lines are rendered inoperable.

37. Mitchell, *Physical Asset*; and D. S. Haviland, *Life Cycle Cost Analysis: A Guide for Architects* (New York: American Institute of Architects, 1977).

### *More Affordable Maintenance*

Another benefit of the people-centric base design is in decreased maintenance costs to overall base infrastructure while ensuring sustained operations. Infrastructure repair and maintenance would be minimized as the linear distance becomes shorter. For roads, different materials can be used to distinguish between vehicle roads and pedestrian streets. For example, for low-vehicle density roads and bicycle paths, cobblestone as a road material has been found to be less costly throughout its lifespan compared to asphalt or concrete.[38] The use of cobblestone or even brick for locations designed to be walkable can also offer a passive traffic calming measure for GOVs.

Furthermore, consolidating areas into distinct and clustered groupings minimizes the utility runs needed for each facility and maximizes the multichannel runs of infrastructure. Walkable areas connecting the facilities within the groupings would further reduce the operational and maintenance costs of the roads. Restricting transportation of the roadways to GOVs or base-provided transit vehicles would also reduce stress loading.

## Sustainable Benefits of Redesign

While sustainability goals for an Air Force base may differ from such goals for cities, the underlying life-cycle cost savings associated with facility sustainability are shared between the two environments. Minimizing outer surface area while maximizing interior space results in reduced construction and life-cycle energy costs and has been adopted in current Air Force dormitory design.[39] Expanding these potential savings to all housing units on base as well as a consolidated support area would lower the yearly infrastructure life-cycle cost.

Consolidating housing from single-family detached units into attached units or apartments increases the density of the useful square footage while decreasing the support infrastructure needed to accommodate each family. The design of such consolidated housing must consider accessibility concerns for dependent family members. These same benefits can also be shared when designing the support hub for the people-centric base.

While the average Air Force base will not see tremendous fluctuations in personnel housed or operating within the base, additions to the housing, supporting, and operational areas remain viable. Furthermore, multi-utility tunnels within the dense people-centric areas are less likely to be damaged by adversarial attacks and can be cheaper and faster to repair, compared to existing utility designs.

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38. Damien Triguax et al., "Life Cycle Assessment and Life Cycle Costing of Road Infrastructure in Residential Neighbourhoods," *International Journal of Life Cycle Assessment* 22, no. 6 (2017), https://doi.org/.

39. *Unaccompanied Housing*.

Sustainable urban design is obtainable through constant and consistent feedback from the occupants of the urban environment.[40] Base designers must interact iteratively and persistently with the urban environment as well as with base personnel to identify current problems to better plan for a modernized Air Force base.[41]

Designers should consider what change would have the greatest impact for their base. Creating a closed-road mass transit system may not be financially feasible in the near term, yet base designers may find implementing a bus system or passenger walking routes on the open-road system more feasible until funding is available. Similarly, designers may find that relocating personnel into existing facility groupings may be more plausible until funding can assist with the construction of permanent grouped facilities. Lastly, they should consider how existing infrastructure runs can become more efficient to support the base.

While policy can be drafted in broad enough terms to affect the necessary organizations and changes to base designs, a separate budget may need to be implemented with its own criteria to compete such projects correctly and competitively. Policymakers could incentivize DoD partnerships with government agencies as well as nongovernment agencies such as the Federal Emergency Management Agency, Department of Energy, Department of Transportation, Department of Housing and Urban Development, National Science Foundation, and National Institute of Building Sciences to assist in converting bases to a modernized base design. Policies should focus on the inherent relationship between the supporting infrastructure and the facilities. A team of designers could experiment with an existing base as a test to determine the feasibility, costs, and problems associated with modernizing current bases.

## Challenges

Historically, adequately funding DoD installation maintenance has been difficult to achieve.[42] The primary challenge of the design overhaul presented in this article is justifying the enormous budget needed to reconstruct bases at an accelerated pace over the current projected pace. A separate fund may need to be established to accommodate the shift in base design principles. This new fund could be utilized to supplement existing funding sources or be the sole fund for modernizing such projects.

Still, even if the funds are made available, the Air Force is deficient in manpower and the necessary skills to implement the changes.[43] Such an overture would require multiple teams of urban designers, architects, and engineers to study and improve on the modernized base

40. Massimo Tadi, Sharooz Manesh Vahabzadeh, and Fabrizio Zanni, "Integrated Sustainable Urban Design: Neighbourhood Design Proceeded by Sustainable Urban Morphology Emergence," *WIT Transactions on Ecology and the Environment* 155 (2012); Reeman Mohammed Rehan, "Sustainable Streetscape as an Effective Tool in Sustainable Urban Design," *HBRC Journal* 9, no. 2 (2013), https://doi.org/; and Marohn, *Strong Towns*.

41. Tadi, Manesh, and Zanni; Rehan; and Marohn.

42. Maestas et al., "Defining Success."

43. Maestas et al.

design throughout their entire careers. The current corporate option for planning and constructing these complicated projects is to employ architect-engineering firms outside of the government. A shift in career fields in the civil engineering squadron to accommodate the workforce necessary to accomplish and construct modernized bases may be feasible.

While revised Unified Facilities Criteria and area development plans would allow for new bases to be modernized, existing bases would struggle to adapt their current makeup. Separate policies and guidance may be needed to determine how an existing base might align with the modernized base design. This would allow for each base to determine the critical path to success through incremental change optimized for their unique locations.

Further, adapting bases to the modernized base design would have impacts on the local economy. For example, car dealerships close to bases rely on military members purchasing a vehicle to navigate both the local area and on base. Current transportation corridors into and out of the base would need to be reevaluated for traffic flow. Gradual changes to the base would generate stress on the local economy as city and transportation design would need to incorporate the proposed end state. While these gradual modifications could benefit a city seeking to progress toward a people-centric environment, the rate at which a base changes may differ from the rate at which the surrounding city changes to integrate with a modernized base design.

Lastly, the modernized design will differ between continental United States bases and deployed locations. The current Air Force stock of deployed structures as well as the inherent difference in likely adversary attacks changes the underlying base design for deployed locations. Inclusion of life-cycle analysis for supporting infrastructure at deployed locations may benefit the location. This analysis will allow base commanders to determine the most efficient equipment and infrastructure that can provide the support necessary to generate their operational effort in both friendly and adverse environments.

## Conclusion

The Air Force's currently established car-centric design for its air bases is not an optimal solution against present and future disruptive events. A people-centric design may be a better solution to the security and integrity challenges it faces. Removing POVs from the base road systems would encourage consolidation efforts for both facilities and supporting infrastructure. In addition to enhancing rapid cross-base transit, consolidated facilities will become multifunctional. Each change will maximize sustainability while ensuring that a modernized base design can adapt to attack scenarios now and in the future.

# Combat Casualty Care

## Engaging Allies and Partners in a DoD Global Trauma System

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As the US national security strategy focuses on Sino-American campaigning in the Indo-Pacific, enhancing the US DoD combatant command trauma system by incorporating Ally and partner nations represents a critical opportunity for improving geostrategic alliances and building partner-nation capacity. With the potential for a theater-wide war, the current security environment highlights the importance of developing a robust trauma system capable of (1) optimizing global health engagement, (2) increasing trauma care readiness, (3) enabling interoperability between the United States and partner nations, (4) enhancing interagency partnerships, and (5) supporting integrated deterrence. This article offers a framework to transform the existing command trauma system into a global trauma system that allows the Department of Defense, working with Allies and partners, to support casualty care in the Indo-Pacific and beyond.

Over the past twenty years, the United States, its Allies, and partners focused on counterinsurgency operations in the Middle East, which encompassed small-scale and unconventional warfare. These operations centered on defeating nonstate actors including Al-Qaeda, ISIS, and the Taliban. Yet, with the withdrawal of US and partner military units from Afghanistan, the 2022 expanded invasion of Ukraine by the Russian Federation, and the continued rise of the People's Republic of China (PRC), the

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2022 *National Security Strategy* transitioned to a new era of global strategic competition.[1] Fused within this grand strategy is the critical priority to out-compete the PRC through integrated deterrence, employing a range of unilateral to multilateral efforts to promote a free and open Indo-Pacific.

China's advancing military capabilities and aspirations increasingly challenge the United States' longstanding position as the sole global superpower. Conventional wisdom holds that the tensions between the two nations could reach the point of conventional military conflict in the near future over a challenge by China to Taiwan's independence. PRC President Xi Jinping has the party's sights on "reunification" with Taiwan, an objective that would require a large-scale amphibious military assault.[2]

Although the United States preserves the notion of strategic ambiguity surrounding the potential defense of Taiwan amid a PRC invasion, an attack could hypothetically lead to large-scale combat operations (LSCO) requiring distributed maritime operations—the strategic dispersal of naval units, sensors, and weapons across a large area within the operations theater—in the Indo-Pacific.[3]

A conventional force-on-force fight within theater-wide multidomain environments has crucial implications for not only the United States but also for regional Allies and partners in the Indo-Pacific area. Conflict with a peer adversary such as the PRC will likely disrupt the system of combat casualty care the United States has created during the past 20 years of conflict in the Middle East. That period saw the lowest case fatality rate and percentage of killed in action in history.[4]

As studies have estimated—including one wargame suggesting 6,960 American casualties in the first three weeks of conflict—future LSCO casualties will likely overwhelm current capacity and clog the evacuation chain.[5] A predicted lack of air superiority coupled with the tyranny of distance, novel precision fires, and gray-zone activities will hinder battlefield trauma care of US, Ally, and partner-nation military and civilian casualties. Consequently, delays in reaching casualty care points, compounded by lengthy time and

1. Joseph R. Biden Jr., *National Security Strategy* (Washington, DC: White House, October 2022), https://www.whitehouse.gov/.

2. Dzirhan Mahadzir, "Xi Jinping Pledges Reunification with Taiwan in New Year's Message," *USNI News*, January 1, 2024, https://news.usni.org/.

3. John Dzwonczyk and Clayton Merkley, "Through a Glass Clearly: An Improved Definition of LSCO," *Military Review*, November 2023, https://www.armyupress.army.mil/; and "Distributed Maritime Operations (DMO)," US Marines [website], August 2, 2021, https://www.marines.mil/.

4. Shawn C. Nessen et al., "Unrealized Potential of the US Military Battlefield Trauma System: DOW Rate Is Higher in Iraq and Afghanistan Than in Vietnam, but CFR and KIA Rate Are Lower," *Journal of Trauma and Acute Care Surgery* 85, no. 1S (July 1, 2018), https://doi.org/.

5. Mark F. Cancian, Matthew Cancian, and Eric Heginbotham, *The First Battle of the Next War: Wargaming a Chinese Invasion of Taiwan* (Washington, DC: Center for Strategic & International Studies, January 9, 2023), https://www.csis.org/.

distance movements to fixed US facilities for definitive care and rehabilitation, will degrade force lethality and decrease the regeneration of combat-capable units.[6]

To care for wounded US, Ally, and partner-nation personnel in this new era, the militaries in question must emphasize evaluating and strengthening globally integrated casualty care. During the Global War on Terror (GWOT), the US military medical system adapted to the operating environment with the support of the DoD Joint Theater Trauma System, which was developed for the US Central Command (USCENTCOM) area of responsibility and modeled after civilian trauma systems that offered integrated care across a geographic region to better organize battlefield care in theater. In 2013, the Joint Trauma System (JTS) was deemed a Defense Center of Excellence, and today it provides battle-injury and nonbattle-injury trauma patients with organized care "at any area of conflict."[7]

In the same manner, the US military medical system must once again adapt to meet the challenges posed by the future battlespace. Bridging the gap between geostrategic security concerns and trauma care in the Indo-Pacific region will require the United States to establish a DoD global trauma system (GTS) led by the JTS. This can be achieved by transforming existing combatant command trauma system capabilities.[8]

US DoD global health engagement is defined as the

> interaction between individuals or elements of DoD and those of a [partner nation's] armed forces or civilian authorities, in coordination with other US Government departments and agencies, to build trust and confidence, share information, coordinate mutual activities, maintain influence, and achieve interoperability in health-related activities that support US national security policy and military strategy.[9]

Within this context, employing global health engagement focused on a DoD GTS can enhance resilience related to global casualty care across a range of military operations.[10] This article aims to describe the evolving geostrategic security environment with relation to the battlefield trauma system, discussing the implications of Sino-American competition on casualty care in the Indo-Pacific. In analyzing how trauma systems support integrated deterrence and augment casualty care systems, this article constructs a

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6. Mason H. Remondelli et al., "Casualty Care Implications of Large-Scale Combat Operations," *Journal of Trauma and Acute Care Surgery* 95, no. 2S (May 31, 2023), https://doi.org/.

7. "About JTS," Joint Trauma System, last modified March 5, 2019, https://jts.health.mil/.

8. Defense Health Agency, *Combatant Command (CCMD) Trauma Systems (CTS)*, Procedural Instruction No. 6064.06 (Washington, DC: Department of Defense [DoD], September 8, 2020), https://www.health.mil/; and Derek Licina and Jackson Taylor, "International Trauma Capacity Building Programs: Modernizing Capabilities, Enhancing Lethality, Supporting Alliances, Building Partnerships, and Implementing Reform," *Military Medicine* 187, no. 7–8 (February 1, 2022), https://doi.org/.

9. Office of the Under Secretary of Defense for Policy, *Global Health Engagement (GHE) Activities*, DoD Instruction (DoDI) 2000.30 (Washington, DC: DoD, July 12, 2017), https://www.esd.whs.mil/.

10. DoDI 2000.30; and "Global Health Engagement," Health.mil, last updated August 4, 2023, https://www.health.mil/.

framework for a DoD global trauma system to strengthen Indo-Pacific security albeit with global applications.

## A Transforming Geostrategic Security Environment

The geostrategic environment over the past two decades was almost singularly focused on rooting out terrorism within the USCENTCOM area of responsibility—a military landscape primarily involving operations in Afghanistan and Iraq. During these periods of intense counterinsurgency fighting, US military and GWOT coalition nation casualties were offered some of the highest levels of medical care ever seen in modern combat.

Data suggests the case fatality rate fell from 55 percent during World War II to 12 percent during the conflicts in Afghanistan and Iraq, while other studies assess the recent rate of survivability was around 98 percent for those who reached surgically capable facilities.[11] Other data from the DoD Trauma Registry suggested a 99.1 percent survival rate amongst casualties from January 2003 to May 2019. Furthermore, unit-specific studies found a Died of Wounds rate as low as 1.7 percent among US Army Rangers in the 75th Ranger Regiment.[12]

This success was dependent upon a variety of factors, including modified clinical practice guidelines such as the increased use of tourniquets and early blood transfusions, as well as decreased medical evacuation transport times to definitive surgical care within the secretary-of-defense-directed 60-minute "golden hour" window.[13] Additionally, air superiority throughout Afghanistan and Iraq allowed for relatively uninhibited intra- and inter-theater evacuation and medical resupply. The focus on two established and resourced theaters of operation within the same geographical combatant command minimized the complexity of the trauma system and the demand for it.

Looking at the future dispersed operating and geostrategic environment in the Indo-Pacific, these advantages may not be present as the United States shifts away from counterinsurgency operations. With an increased focus on integrated deterrence, great

11. Jeremy W. Cannon et al., "Comprehensive Analysis of Combat Casualty Outcomes in US Service Members from the Beginning of World War II to the End of Operation Enduring Freedom," *Journal of Trauma and Acute Care Surgery* 89, no. 2S, suppl. 2 (August 1, 2020), https://doi.org/; Robert L. Mabry and Robert DeLorenzo, "Challenges to Improving Combat Casualty Survival on the Battlefield," *Military Medicine* 179, no. 5 (May 2014), https://doi.org/; and Brian J. Eastridge et al., "Death on the Battlefield (2001–2011): Implications for the Future of Combat Casualty Care," *Journal of Trauma and Acute Care Surgery* 73, no. 6, suppl. 5 (2012), https://doi.org/.

12. Steven G. Schauer et al., "16 Years of Role 1 Trauma Care: A Descriptive Analysis of Casualties within the Prehospital Trauma Registry," *Medical Journal*, US Army Medical Center of Excellence, no. 44–49 (2021), https://pubmed.ncbi.nlm.nih.gov/; and Russ S. Kotwal, "Eliminating Preventable Death on the Battlefield," *Archives of Surgery* 146, no. 12 (December 1, 2011): 1350, https://doi.org/.

13. Jeffrey T. Howard et al., "Use of Combat Casualty Care Data to Assess the US Military Trauma System during the Afghanistan and Iraq Conflicts, 2001–2017," *JAMA Surgery* 154, no. 7 (July 1, 2019), https://doi.org/; and Russ S. Kotwal et al., "The Effect of a Golden Hour Policy on the Morbidity and Mortality of Combat Casualties," *JAMA Surgery* 151, no. 1 (January 1, 2016): 15, https://doi.org/.

power competition, and irregular warfare, this emerging operating environment may feature LSCO with anti-access/area-denial technology and multidomain warfare across multiple theaters.

Conflict with nations in the Indo-Pacific such as China may feature other unique challenges: The United States and its Allies and partners will encounter obstacles brought on by China's gray-zone tactics, including its creation of artificial islands for purportedly economic purposes that actually serve to increase its military's access, presence, and control over the region.[14] Because of this, ship-based naval medicine within distributed maritime operations will see a heightened role in comparison with the land-based conflicts of the Global War on Terror, while integrated deterrence and irregular warfare will demand novel medical planning solutions.

Furthermore, rapid advances in the cyber, electromagnetic, and information domains will threaten US communications globally, which could critically disrupt casualty care. This includes medical evacuation, resupply, hospital operations, health data security, and telemedicine.[15] These multidomain threats will challenge not just US personnel, but also Allies and partners in the Indo-Pacific region. It is paramount that the United States invest in regional partnerships to expand capacity, integrate plans, and strengthen alliances to adapt to this new geostrategic environment.

## Obstacles to Trauma Care

Potential conflicts against peer adversaries, such as the PRC, resulting in large-scale combat operations and distributed maritime operations highlight challenges in providing trauma care in the Indo-Pacific. These obstacles are described below through the lens of the casualty care continuum (fig. 1).

14. Ryan M. Leone et al., "Disguised among the Sea: The Implications of Artificial Islands on Casualty Care in the Indo-Pacific," *Military Medicine*, January 1, 2024, https://doi.org/; and Bonny Lin et al., *A New Framework for Understanding and Countering China's Gray Zone Tactics* (Santa Monica, CA: RAND Corporation, March 30, 2022), https://doi.org/.

15. "Electromagnetic Spectrum Operations: DOD Needs to Address Governance and Oversight Issues to Help Ensure Superiority," US Government Accountability Office (GAO), December 10, 2020, https://www.gao.gov/; and "Challenges Facing DOD in Strategic Competition with China," *GAO National Security Snapshot* (Washington, DC: GAO, February 2022), https://www.gao.gov/.

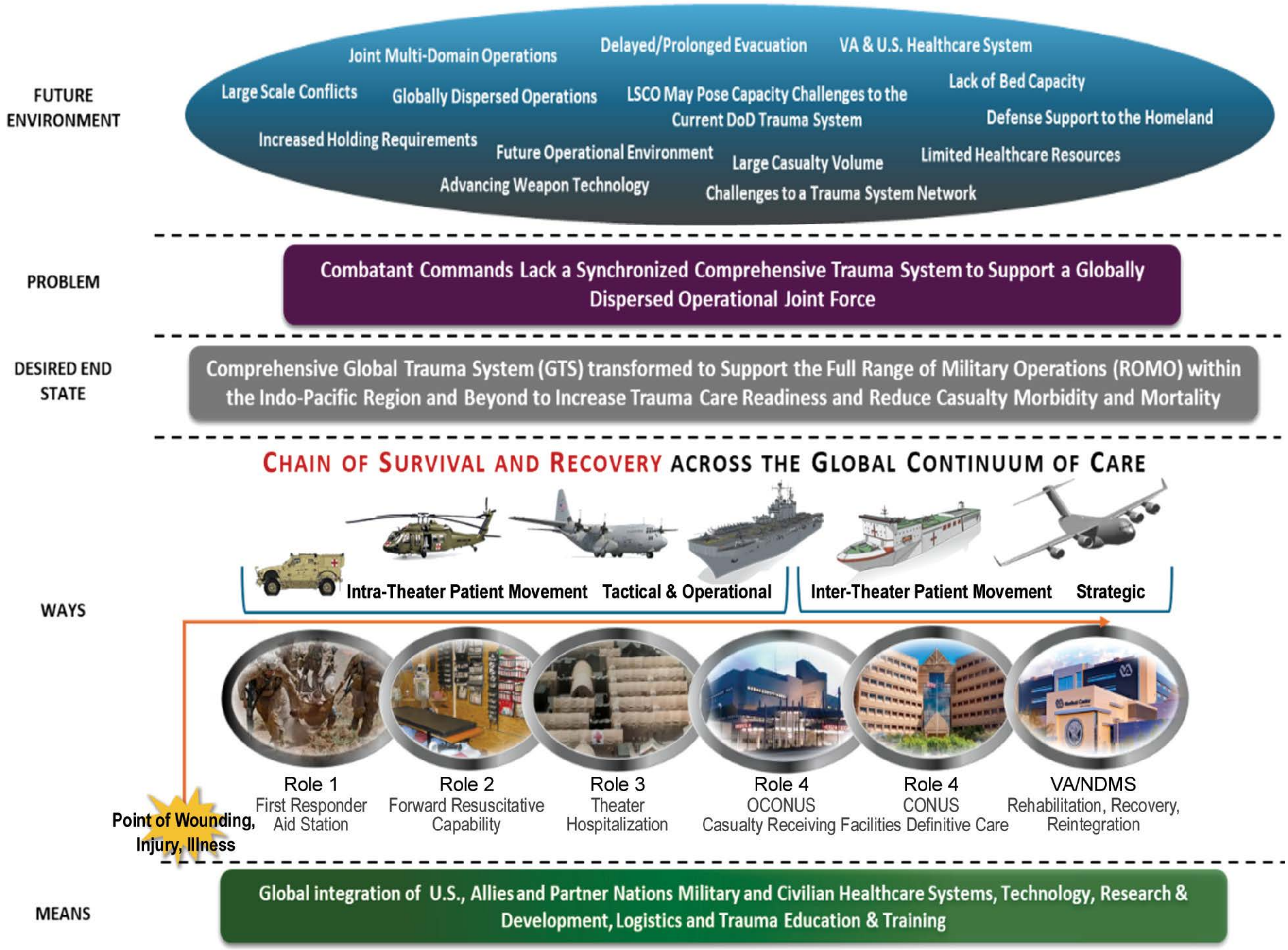


**Figure 1. The casualty care continuum**

Beginning with point-of-injury care and Role 1 (unit-level medical care) operations, limited evacuation capabilities may force prehospital providers—for example, medics and corpsmen—to provide care for upwards of hours to days before casualties can be offered even limited surgical care in austere settings in close proximity to the front line. As a result, prehospital providers must be thoroughly trained to support prolonged casualty care to ensure the highest survivability in resource-limited environments. In addition, they must also be equipped with the appropriate supplies to meet this new extended scope of practice, be physically prepared to carry more extensive medical supplies without limiting tactical mobility, and be virtually connected to higher-level providers through reach-back communications platforms such as the Advanced Virtual Support for Operational Forces program.[16]

Even with augmented support to address the challenges in this shift in trauma care, prehospital providers will still be under-resourced in providing casualty care. With this limitation in capabilities, additional focus will need to be on evacuation to far-forward surgical care with evacuation as soon as feasible while providing en-route care. With the elongated period between the point of injury and evacuation, these patients may enter physiological states akin to those of patients traditionally cared for in intensive care units, but with no availability of a wide array of tools, providers, and resources in the field.

This provision of en-route care, whether it be from the point of injury to Role 2 far-forward surgical support—forward resuscitative capability—or from the latter to Role 3 and 4 military treatment facilities (MTFs)—in this case, theater hospitalization and continental United States casualty receiving facilities, respectively—will similarly require trained, equipped, and remotely supported providers to offer care at an expanded scope of practice to casualties in complex physiological states.

These en-route providers will likely need to offer this high-level care in substandard environments. Operating on low-flying rotary-wing aircraft may be possible, but providing care during clandestine casualty evacuation on land or sea employing local partner-nation capability may need to be considered. This is especially true given that air evacuation will be significantly limited in the weapon engagement zone—where adversarial weapon systems can target Allied platforms—and that surface connectors in the evacuation chain will move at a far slower rate.

Once intra-theater transportation to Role 2 facilities augmented by far-forward, surgical teams is completed, surgeons operating on patients with complex wounds, infections, and physiologies in low-resource settings will encounter similar obstacles. The limited bed space of Role 2 facilities can quickly become bottlenecked. Limitations on evacuation to Role 3 MTFs will further stress these resources, potentially creating a bottleneck of the already limited Role 2 MTFs.

16. Robert D. McLeroy et al., "Advanced Virtual Support for Operational Forces: A 3-Year Summary," *Military Medicine* 187, no. 5–6 (October 22, 2021), https://doi.org/.

These extraordinary circumstances could pose the unique challenge of forcing emergency physicians and surgeons to utilize situational triage guidelines, putting medical decisions within the commander's intent in scenarios with limited resupply and evacuation, intensive need for resources, and balanced survival outcomes.[17] Military physicians should not only be equipped to operate in low-resource environments but also receive training in ethical decision-making, especially in the context of mass-casualty scenarios. The potential Indo-Pacific conflict highlights educational needs beyond medical care, stretching into Joint, interagency, and multinational operational planning of both evacuation and treatment authorities and priority.

The unpredictability of evacuation to Role 3 MTFs means Role 2 teams must keep certain patients in a constant state of preparedness for movement, even when patient stability is in question. When evacuation to Role 3 MTFs can be executed, similar demands will be seen with en-route casualty care and the subsequent treatment of complex casualties. Larger distances, terrain that restricts maneuver, and expansive bodies of water will separate Role 2 and Role 3 facilities, while a lack of air superiority, with well-positioned adversarial surface-to-air and air-to-air missiles or potential electromagnetic weapons to use against friendly vehicles, may further complicate the journey. This may result in a requirement for transport to occur between different Role 2 facilities, or even from Role 2 to less-capable platforms, before arrival at a Role 3 site.

Transportation via fixed-wing aircraft from Role 3 to overseas and continental Role 4 MTFs, whether they are US- or partner-owned facilities, will also be complicated by long distances and potential threats to evacuation platforms. Finally, once these casualties can be transferred stateside, the lengthy rehabilitation process and large number of casualties will force the activation of the National Disaster Medical System in civilian hospitals once DoD and Veterans Affairs hospitals have reached capacity, ensuring that a network of providers and supplies are in place to offer them care.[18]

Overall, the current US approach to warfare is centered on casualty aversion. Yet the reality of LSCO and multidomain operations conflict is that casualties may be significant and accumulate rapidly. Medical plans must account for the logistics of such intensive holding, en-route care, evacuation, and rehabilitation needs.[19]

17. Brian Beldowicz et al., "Situational Triage: Redefining Medical Decision Making for Large-Scale Combat Operations," *Military Review*, July–August 2022, https://www.armyupress.army.mil/.

18. Clark J. Lee et al., "The National Disaster Medical System and Military Combat Readiness: A Scoping Review," *Journal of Trauma and Acute Care Surgery* 93, no. 2 (August 1, 2022), https://doi.org/.

19. Jennifer Wilson, "Casualty Aversion, the Challenge in Medical Planning for LSCO," Small Wars Journal, June 8, 2018, https://smallwarsjournal.com/.

## A Global Trauma System for the Department of Defense

To overcome global casualty care challenges generated by the future strategic and military operational environment, the Department of Defense should establish a global trauma system. In the United States, formally organized civilian trauma systems have been shown to decrease the mortality of severely injured patients by 15 to 20 percent.[20] As mentioned, military medical leaders during the Global War on Terror followed this model and created a system to care for injured service members on the battlefield that eventually became the DoD Joint Trauma System.

Standardizing the way the military performs trauma care, the JTS enables the collection and analysis of injury and treatment data to fall under a single system across the continuum of care led by a single organization. Real-time modifications of clinical practice guidelines, casualty evacuation command implementation, and subject-matter expert guidance to combatant commanders were associated with a 44 percent reduction in mortality from the outset of the conflict.[21]

Centralizing the trauma care system was one of the leading reasons for the reduction of preventable deaths and increased combat casualty survival on the battlefield during the GWOT. Using the features of this optimized trauma care system in LSCO and multidomain operations conflicts will be vital in maximizing US, Ally, and partner-nation casualty survival and maintaining combat force lethality.

A global trauma system will require transforming combat trauma systems across all geographic combatant commands, including integrating with Ally and partner-nation operational medicine and fixed-facility trauma capability. The combatant command trauma system serves as a crucial asset for these commands and the Department of Defense more broadly by ensuring rapid and effective medical care for injured service members within their respective operational theaters. By providing dedicated assets, this system enhances the geographic combatant commands' ability to sustain military operations and support mission success across the range of trauma system tasks, functions, and responsibilities.

Yet, despite its effectiveness at the individual command level, focusing primarily on the needs of US military personnel through US military treatment facilities, the combatant command trauma system lacks integration at an international level and with Allies and partners. Collaboration and integration with international trauma systems could offer significant benefits, including enhanced interoperability, resource sharing, and collective response capabilities in multinational operations. Integrating Allies and partners into the command-level and broader DoD global trauma system would also facilitate the exchange of best practices, promote standardization of trauma care protocols and collaborative trauma research and development, and ultimately strengthen overall medical readiness and resilience in Joint and combined military operations.

20. Ellen J. MacKenzie et al., "A National Evaluation of the Effect of Trauma-Center Care on Mortality," *New England Journal of Medicine* 354, no. 4 (January 26, 2006), https://doi.org/.

21. Howard et al., "Combat Casualty Care Data."

This is especially true within and around the First Island Chain, a Pacific geographical area essential to military operations that features limited US trauma system capability. As the closest island chain to the PRC, it can be theorized that initial LSCO would be conducted within this region, and the Second Island Chain, which includes Guam, might serve as a buffer zone bordering the theater. A system that creates an interconnected lattice of trauma centers within Ally and partner nations—such as Australia, Indonesia, Japan, Malaysia, Papua New Guinea, the Philippines, South Korea, Vietnam, and Taiwan—will be essential for delivering far-forward care for US, Ally, and partner-nation personnel (fig. 2).

The Defense Department has worked with each of these countries in the past through a range of global health engagement efforts, some including casualty and trauma care.[22] This could and should include military and civilian personnel supporting or affected by the range of military operations. Building on these existing DoD global health engagement efforts with enhanced medical capabilities becomes even more important when considering the possibilities for delayed evacuation, extended evacuation routes over the Pacific, and the previously mentioned potential for Role 2 MTF bottlenecks.

22. Joshua Michaud et al., "Militaries and Global Health: Peace, Conflict, and Disaster Response," *Lancet* 393, no. 10168 (January 2019), https://doi.org/; Terry M. Rauch et al., "US Department of Defense Global Health Engagement: Supporting Global Health Security, Readiness and Interoperability," *BMJ Military Health*, December 22, 2023, https://doi.org/; Derek Licina, "The Military Sector's Role in Global Health: Historical Context and Future Direction," *Global Health Governance* 6, no. 1 (2012); and Thomas Cullison, Charles Beadling, and Elizabeth Erickson, "Global Health Engagement: A Military Medicine Core Competency," *Joint Force Quarterly* 80 (January 1, 2016), https://ndupress.ndu.edu/.

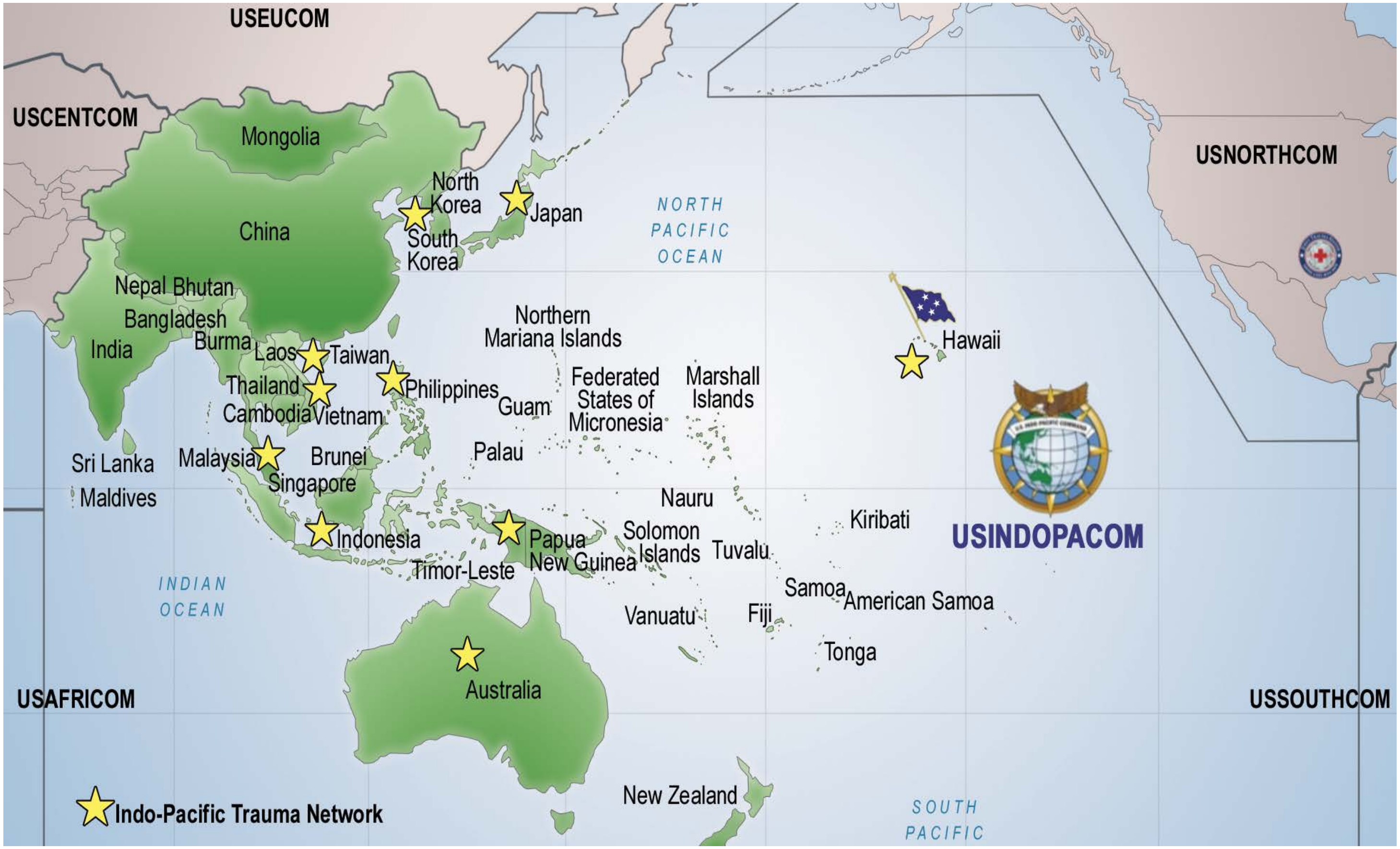


Figure 2. Conceptual member states of a globally integrated trauma system

During a potential conflict in the US Indo-Pacific Command, the proportion of estimated casualties coming from ground forces and naval forces will vary. The ratio will fluctuate based on the timing and breadth of operations by forward-assigned assets compared with that of amphibious assaults or other littoral operations. Nevertheless, hospital ships may prove valuable in augmenting the casualty treatment and evacuation system. The Navy's humanitarian efforts with the USNS *Comfort* and USNS *Mercy* have already proved fruitful in providing care while strengthening partnerships globally.[23]

Furthermore, the United States has announced the creation of three new expeditionary medical ships to more than double its current medical ship fleet, signaling its investment in supporting ship-based trauma care and evacuation.[24] This expanded utilization of hospital ships is likely the first sign of increased preparations to ready trauma personnel and operations for possible Indo-Pacific conflict. With hundreds of hospital beds and a dozen operating rooms, each ship could serve to facilitate operations at various points on the trauma lattice, similar to the way hospital ships were used during World War II. These hospital ships may also serve as large, mobile resupply vessels for Class VIII (medical) materials, including blood.

Yet despite the capability provided by a growing number of hospital ship platforms, shortfalls remain in closing anticipated trauma system gaps during large-scale combat operations and associated distributed maritime operations. The proposed DoD global trauma system would maximize limited trauma care resources and mitigate the risk posed by the anticipated casualty volume and rate.

Moreover, such a system would promote the JTS concept of expeditious medical performance optimization. This concept involves the collection of injury and treatment data, analysis of the quality of care delivered, development of evidence-based clinical practice guidelines, and the utilization of these outcomes to modify education and training for the future.[25] Such an automated, system-wide data-collection process would maximize trauma care performance, with appropriate consideration given to ensuring such collection aligns with information privacy and data limitations of Ally and partner nations.

Data centralization and inherent adaptability were essential components of the strategy that improved mortality in the GWOT by increasing US, Ally, and partner-nation

23. Alicia G. Sykes et al., "Trends in Surgical Case Volume during Pacific Partnership Missions Onboard USNS Mercy," *Military Medicine* 188, no. 7–8 (December 15, 2021), https://doi.org/; Shane Jensen et al., "Integration of Surgical Residency Training with US Military Humanitarian Missions," *Journal of Surgical Education* 72, no. 5 (September 2015), https://doi.org/; "USNS Mercy Delivering Medical Care, Humanitarian Assistance to Pacific Islands," Indo-Pacific Defense Forum, November 6, 2023, https://ipdefenseforum.com/; and Alex Wilson, "Navy Hospital Ship Wraps Up Annual Humanitarian Mission in the Pacific," *Stars and Stripes*, January 25, 2024, https://www.stripes.com/.

24. Heather Mongilio, "SECNAV Del Toro Names Next-Generation Hospital Ship Bethesda," *USNI News*, January 9, 2024, https://news.usni.org/.

25. Jennifer Gurney et al., "The 'Survival Chain': Medical Support to Military Operations on the Future Battlefield," *Joint Force Quarterly* 112 (February 16, 2024), https://ndupress.ndu.edu/.

combat casualty survival and return to duty.[26] The execution of care optimization is however limited by the ability to coordinate and communicate with points in the lattice, reinforcing the importance of pre-conflict multination partnerships.

Operationally, a DoD GTS structure could enable the quick maneuvering of far-forward surgical assets to the medical decisive point, the swift movement of casualty evacuation platforms to collect injured service members during breaks in fighting, and the prompt medical situational awareness for onward patient movement. A modified five-pronged approach originally proposed by one study is necessary to ensure the development of a global trauma system for the Department of Defense, and in collaboration with Allies and partners.[27]

### *(1) Optimize Global Health Engagement*

- Optimize ongoing global health engagement, security cooperation, and formal development efforts conducted across the various geographic combatant commands by the total force—active-duty, guard, and reserve—and the interagency in support of a DoD GTS.

### *(2) Increase Trauma Care Readiness*

- Leverage Ally and partner-nation trauma resources, capabilities, and capacities to support combined military operations.
- Enhance partner-nation medical infrastructure, contingency planning processes, prehospital care guidance, and advanced evacuation assets.
- Share novel trauma care research, guidelines, and best practices to provide measurable benefits to all stakeholders.

### *(3) Enable Interoperability*

- Enable effective and efficient allocation of US, Ally, and partner-nation trauma care resources, casualty evacuation platforms, and personnel.
- Standardize system-wide trauma care doctrine and associated tactics, techniques, and procedures used for the execution of successful treatment and evacuation collaboration.
- Establish trust and build rapport among US, Ally, and partner-nation military medical personnel.

26. Donald H. Jenkins and Jeffrey A. Bailey, "Origins and Importance of the Joint Trauma System," *Journal of Trauma and Acute Care Surgery* 81, no. 5 (2016).

27. Kyle Remick and Eric Elster, "Trauma Care in Support of Global Military Operations," *Joint Force Quarterly* 86 (January 26, 2016), https://ndupress.ndu.edu/.

### *(4) Enhance Interagency Partnerships*

- Build long-term trauma care relationships with Ally and partner nations to enhance trauma care efforts between the Defense Department, Department of State, US Agency for International Development (USAID), and nongovernmental organizations.
- Maintain robust military-to-military, military-to-civilian, and civilian-to-civilian trauma care partnerships involving the Defense Department, State Department, USAID, academic universities, and hospital institutions.

### *(5) Support Integrated Deterrence*

- Integrate trauma systems across military domains and nonmilitary domains, such as health.
- Integrate across all geographic combatant commands and link back to the homeland through the National Disaster Medical System.
- Integrate across the spectrum of conflict with primary efforts in shaping operations.
- Integrate with diplomacy and development efforts to take a government "3D approach," that is, addressing defense, diplomacy, and development.
- Integrate with Allies and partners through mutual investment and risk mitigation.[28]

## Engagement Framework

Strengthening casualty care capacity in the Indo-Pacific region and beyond involves creating a framework for trauma system efforts. First, the United States, in conjunction with Allies and partners, must determine the trauma system requirements to collectively support large-scale combat operations, current capabilities, gaps, and solutions to mitigate the current trauma system risks. A holistic analysis of expected needs, based on casualty estimates, will create a standard to which current capabilities can be compared. Identified gaps in capacity and capability can then be addressed.

Second, a strategic transformation concept of operation should be developed to transform the geographic combatant command trauma system into a DoD GTS that can support the identified requirements. This would include establishing the legal framework for internal (Defense Department), interagency (for example, State Department and USAID), multilateral (World Health Organization [WHO]), and nongovernmental organizations to provide trauma care to US, Ally, and partner-nation military and civilian personnel even when it extends beyond their traditional scope of coverage.

28. Robbert Gabriëlse, "A 3D Approach to Security and Development," *Connections* 6, no. 2 (2007).

Importantly, this framework and combined efforts could expand to support the WHO Global Emergency and Trauma Care Initiative, which addresses injuries that killed 4.4 million people around the world and constituted 8 percent of all deaths in 2019.[29] Nearly 90 percent of injury deaths take place in low- and middle-income countries. The DoD GTS efforts could assist partner nations in closing this gap.[30]

Across the interagency, DoD civilian employees are traditionally only covered for space-available care under TRICARE, and State Department providers are only authorized to provide care to chief-of-mission personnel whose host agencies have contributed financially to gain coverage. In each of these situations, department policies or congressional legislation should be proactively updated and/or developed to offer streamlined protocols that eliminate any financial or administrative obstacles that could prevent patients from receiving care from interagency partners.

Furthermore, the rules that allow DoD providers to offer trauma care to foreign nationals during conflict or humanitarian settings should be extended to Department of State providers at international embassies and consulates. This would allow providers to apply their expertise in the local community and hospitals to strengthen relationships rather than just serving chief-of-mission personnel. Removing logistical and administrative barriers to care will enable the Joint Trauma System and the DoD GTS to incorporate interagency resources into their strategy and associated plans for not just DoD casualties, but all US, Ally, and partner-nation casualties that need definitive care within and outside the theater of operations.

These efforts should extend across all phases of operations including, but not limited to, defense support to civil authorities, integrated deterrence, conflict, and stabilizing activities that rebuild countries after conflicts end.[31] Doing so would increase the scope of the Department's global health engagement activities supporting US Allies and partners employing the total force as well as interagency partners to support global health security.

Increased interagency and multilateral collaboration would facilitate information-sharing regarding the current state of US, Ally, and partner-nation trauma system capabilities through completed assessments. This should minimize the intrusiveness of assessments on potential partners, reduce the cost of conducting repeated assessments, and maximize efficiency by ensuring that all collaborators with a need to know are informed for their respective planning purposes.

Third, it is important to ensure that global health engagement, development, and diplomacy efforts established through the DoD GTS are intended to primarily serve US, Ally, and partner nations' regional security and defense strategies, including their domestic health security needs for trauma care. Global stakeholders should understand that system-wide

29. "Global Emergency and Trauma Care Initiative," World Health Organization (WHO), 2024, https://www.who.int/; and "Injuries and Violence," WHO, March 19, 2021, https://www.who.int/.

30. "Global Emergency."

31. *Joint Campaigns and Operations*, Joint Publication 3-0 (Washington, DC: Chairman of the Joint Chiefs of Staff, June 18, 2022), https://www.dau.edu/.

agreements will target locations, capacities, and capabilities pertinent to shared military and global health security objectives between the United States and its partners.

Global health engagement should focus on mutual benefit, address systemic issues, and enhance security cooperation—in short, it should serve as a a form of soft power.[32] These efforts may include enhancing highly capable trauma centers in existing Ally and partner nations. They may also include establishing trauma centers in low- and middle-income countries with capabilities that could both improve local care and accept American casualties en route to Role 4 facilities during contingency operations. The selection of a trauma system site should align with established combatant command campaign plans and the existing geographic combatant command trauma system. Geographic diversity, surge capacity, and strength of preexisting relationships through treaties and defense cooperative agreements should also factor into site selection processes.

Last, Ally and partner nations selected as part of the DoD global trauma system should undergo an assessment and capability development process. While many of the potential nations in the area of responsibility have been assessed by various agencies, often these reports lack standardization, verification, and collaboration. Consequently, increased interagency collaboration should include information-sharing about foreign capabilities to maximize efficiency, save costs, and reduce the burden on partner nations.

As discussed, enhancing Ally or partner-nation trauma systems will be crucial in supporting military operations in regions where US military resources are limited or not readily available. This may be due in part to the dispersion and demands of LSCO in the Indo-Pacific and the resulting diminished capability of the United States to provide immediate trauma care to service members. To integrate the medical capabilities of such partner nations to create a global network for casualty care, a formal method that focuses on both evaluation and enhancement of existing trauma systems is critical.

The Global Trauma System Evaluation Tool (G-TSET), developed by an international team of military and civilian health care providers and other experts and piloted in South Sudan, is one such proposed tool. This capability enables trauma systems assessments in a variety of low-resource settings and serves as a framework for "nation-centered development" based on identified gaps.[33] Findings using this tool form the basis of a system gap analysis in trauma and emergency care that, with the input and support of Allied or partner-nation military and medical leadership, can be targeted for the creation of a short- and long-term strategy. This specific tool identified critical components of a trauma system for evaluation, including leadership and organization, prevention of injuries, access to care, initial injury care and resuscitation, acute injury care, rehabilitation, and education, research, and quality improvement.

32. Aizen Marrogi and Saadoun Al-Dulaimi, "Medical Diplomacy in Achieving U. S. Global Strategic Objectives," *Joint Force Quarterly* 74 (July 1, 2014), https://ndupress.ndu.edu/.

33. Kyle N. Remick et al., "Development of a Novel Global Trauma System Evaluation Tool and Initial Results of Implementation in the Republic of South Sudan," *Injury* 45, no. 11 (November 2014), https://doi.org/.

The use of an assessment such as the G-TSET or another approach developed in concert with the JTS, the American College of Surgeons, Joint Commission International, or WHO could ensure trauma system readiness, identify and prioritize deficiencies, and implement necessary changes unique to an Ally or partner-nation medical care facility. This would ultimately allow for a more integrated military and civilian trauma system while also bolstering the capacity of partner nations to care for their civilian trauma patients outside of regional conflicts.

Expanding beyond military-to-military relationships, the DoD global trauma system should consider whole-of-government treaties and agreements to support a military-civilian trauma system—in partnership with the Department of State, Health and Human Services, and USAID. This could include updating and expanding existing global health engagement efforts and health care resource-sharing agreements with Ally and partner nations to set the conditions necessary to generate and share bed capacity in time of need.[34] Given notice, Ally and partner nations per bilateral agreements could clear beds—for instance, cancel elective procedures—to provide capacity for DoD, Ally, and partner-nation casualties in support of an LSCO event. Through these agreements, Ally and partner nations could be reimbursed by the Department of Defense for the treatment of DoD military casualties and other beneficiaries. This concept is modeled after the approach used by the US government with private-sector medical facilities in the National Disaster Medical System, though in this case it would extend across international borders.

## Conclusion

Although this article focuses on the establishment of a trauma system to augment casualty care and alliances in the Indo-Pacific region, a DoD global trauma system would truly be global in nature and application. Despite regional differences in terrain and adversaries, the broader obstacles in a multidomain, large-scale combat operations environment, plus the strategies that the United States should follow to address them, remain the same. This includes Ally and partner-nation capabilities at every level of care, the complete interoperability of trauma care across US agencies and with US Allies and partners, and the enhancement of Ally and partner-nation health systems to address their own domestic needs.

These efforts serve as an integrated system for the United States and its Allies and partners to draw from across the range of military operations in each region of the globe, with particular emphasis on the Indo-Pacific, where the most pressing threat exists.

To move a DoD global trauma system concept from proposal into practice, congressional support to authorize a pilot program through the National Defense Authorization Act (NDAA) would assist the Defense Department in addressing a potential national security threat of limited trauma system capability and capacity in support of integrated

34. Derek Licina et al., "Expanding Global Health Engagement through Multilateral Security Organizations," *Military Medicine*, December 11, 2023, https://doi.org/; and Lee et al., "National Disaster Medical System."

deterrence and LSCO. The Department of Defense and the interagency could undertake a pilot program to develop and test ways to strengthen international military-military and military-civilian interoperable trauma systems to care for the nation's casualties and support international partners in doing the same. The DoD GTS would directly support the DoD Unified Command Plan, theater campaign plans, the State Department, USAID Development Joint Strategic Plan Fiscal Year 2022–26, and select partner country US Ambassador Integrated Country Plans.[35]

The DoD GTS pilot would seek to mitigate injury risk to military forces and civilians from the United States, its Allies, and partners, while eliminating preventable deaths and disability through prevention and evidence-based care. This program would be designed to increase medical surge capabilities and capacity by strengthening interoperable partnerships with key Allies and partners across regional combatant commands to care for the nation's combat casualties while supporting these Allies and partners in doing the same. The United States, its Allies, and partners that are working together to support global security, peace, and health deserve nothing less.

35. *Joint Strategic Plan, FY 2022-2026* (Washington, DC: US Department of State [DoS] and US Agency for International Development, March 2022), https://www.usaid.gov/; and *Integrated Country Strategy: Philippines* (Washington, DC: DoS, March 21, 2022), https://www.state.gov.

***The New Makers of Modern Strategy: From the Ancient World to the Digital Age***
Edited by Hal Brands. Princeton University Press, 2023, 1,158 pp.

*The New Makers of Modern Strategy* is the latest update to the classic compendium first edited by Edward Mead Earle in 1942 and last updated in 1986 by Peter Paret. Unlike Earle or Paret, who were historians, the editor of this most recent volume, Hal Brands, is a political scientist. Brands is the Henry A. Kissinger distinguished professor of global affairs at the Johns Hopkins University School of Advanced International Studies and a resident scholar at the American Enterprise Institute. The latest version of this anthology consists of 45 essays from a veritable *Who's Who* in contemporary strategic studies, with a couple of contributors—Williamson Murray and S. C. M. Paine—contributing two essays. Eight essays from the previous volume have received a fresh treatment in *The New Makers*.

*The New Makers* has twice as many essays as the original *Makers of Modern Strategy* and slightly more than one and a half as many as the Paret edition.[1] This reflects an attempt to cast a wider net than its predecessors in terms of both the periods and material covered, such as the inclusion of new domains and a shift from the bipolarity of the Cold War to a multipolar world. In this, it achieves mixed results. Despite its subtitle, the ancient world is an afterthought. Only two entries cover strategy in the period prior to Machiavelli—the earliest strategist discussed in the prior editions—in contrast to four that touch on the First World War.

The book does a better job when expanding the range of the *Makers* series. It does this through the inclusion of essays on strategy in non-Western contexts and on the economic aspects of strategy. Among the first, Paine's and Elizabeth Economy's essays are especially noteworthy, and serve as valuable introductions to Chinese thinkers such as Sun Yat-Sen, whom Western strategists would be well advised to become familiar with. The contributions by James Lacey and by Eric Helleiner and Jonathan Kirshner on the relationship between economics and strategy are some of the best contributions to the volume.

Yet Brands' attempt to broaden the *Makers* perspective is not always successful. Kori Schanke's essay on "Strategic Excellence: Tecumseh and the Shawnee Confederacy" and Priya Satia's "Strategies of Anti-Imperial Resistance" are among the weakest of the essays in this volume. Both pieces could have been sacrificed in favor of addressing some of the omissions in the earlier editions, and in this specific volume. Carter Malkasian's essay "Strategies of Counterinsurgency and Counter-Terrorism after 9/11" is one of several contributions that are of uneven quality. The portion on counterterrorism is valuable and highlights how domestic politics and fiscal realities impact strategy, key factors that are often overlooked by military leaders. Yet the section on counterinsurgency borders on hagiography and would have been better served by a more skeptical voice like that

1. Edward Meade Earle, ed., *Makers of Modern Strategy: Military Thought from Machiavelli to Hitler* (Princeton: Princeton University Press, 1943); and Peter Paret, ed., *The Makers of Modern Strategy from Machiavelli to the Nuclear Age* (Princeton: Princeton University Press, 1986).

provided by Gian Gentile.[2] Overall, the uneven nature of the essays in this collection leaves one with the feeling that a third of them could have been omitted entirely.

Despite the greatly expanded nature of *The New Makers*, once again there is no essay on Julian Corbett. Airpower theorist John Warden and the ever controversial but often-cited John Boyd are both deserving of coverage but also go unmentioned. As in the previous edition, geopolitics is overlooked. An essay on Halford J. Mackinder and Nicholas J. Spykman would have been valuable and would have served to complement Derwent Whittlesey's on Karl Haushofer in the original edition. Despite the ubiquity with which terms like hybrid, gray zone, and irregular warfare are thrown around, the debate about their usefulness as intellectual constructs is far from settled, and an essay by Donald Stoker on the topic would have been a welcome addition.

The inclusion of new domains is discussed in Joshua Rovner's "Strategy and Grand Strategy in New Domains" and is one of the more useful essays in the volume. He reminds us that there is no magic technological solution that leads to cheap victory. By successfully tying the new domains of cyberspace and space to the past, Rovner illustrates how logistical, organizational, and fiscal realities will define the realm of the possible. Ultimately, strategic success requires integrating capabilities from both new and existing domains. One can see a future edition of *Makers* including a more expansive examination of strategy as it relates to space and cyberspace.

Lawrence Freedman's opening essay on the idea of strategy is, like all his work, insightful. Yet it is essentially a reworking of two pieces that were previously published in the *Texas National Security Review*.[3] In addition to those contributions already singled out for praise, among the most valuable essays in the book are Walter Russell Mead's on the strategic legacy of ancient Greece and Rome, Michael Leggiere's on "Napoleon and the Strategy of the Single Point," and Iskander Rehman's discussion of French strategy in the seventeenth century.

Hew Strachan's treatment of Carl von Clausewitz is an example of how fresh insights can be found in oft-studied material. At the same time, Dimitry Adamsky's discussion of the revolution in military affairs and Thomas Rid's examination of the intelligence revolution are thoughtful pieces that bring the *Makers* series into recent history. The volume concludes with an excellent essay by John Lewis Gaddis that neatly summarizes and ties together the work by the preceding authors.

*The New Makers* embraces a broader conception of strategy than the 1986 version, which was firmly focused on war. This reflects not so much an evolution of the term strategy but a return to its use in the original Earle edition. Yet, in doing so it unwittingly raises questions of who makes strategy and at what level it is made. Because of the nature

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2. See, for example, Gian Gentile, *Wrong Turn: America's Deadly Embrace of Counterinsurgency* (New York: New Press, 2013).

3. See Lawrence Freedman, "The Meaning of Strategy, Part I: The Origin Story," *Texas National Security Review* 1, no. 1 (December 2017); and Freedman, "The Meaning of Strategy, Part II: The Objectives," *Texas National Security Review* 1, no. 2 (2018).

of the volume—a collection of essays that examine practically the entire span of recorded history across the globe—this book is ill-suited to answer this question or to untangle the nuances between policy, grand strategy, and strategy.

Despite this, *The New Makers of Modern Strategy* is essential reading for courses on strategy. It does not replace the previous two volumes but serves as a useful addition and update by expanding the historical periods, topics, and cultural backgrounds addressed in the *Makers* series. The uneven nature of this work, however, means that it is best dipped into selectively.

**Lieutenant Colonel Wilson C. Blythe Jr., USA, PhD**

***Fight for the Final Frontier: Irregular Warfare in Space***
John J. Klein. Naval Institute Press, 2023, 264 pp.

*Fight for the Final Frontier* plots irregular warfare strategic theories from traditional warfighting domains to space, arguing that established military strategic thought on limited warfare is valid in this newly recognized domain. John Klein, a retired US Navy commander with 22 years of service as a naval flight officer, has written extensively on space strategy and deterrence and is currently an adjunct professor at George Washington University's Space Policy Institute and Georgetown University's Strategic Studies Program. A clearly established academic in the field, Klein builds on his previous work on space strategy to demonstrate how irregular strategies might influence the execution of space warfare by the United States, its Allies, and its partners. The book considers a range of strategic theories applied to historical vignettes, and whilst not exclusively focused on lessons from the maritime domain, it does follow the general trend of military space literature by focusing on maritime synergies.

Klein corrals a variety of strategic concepts across eight chapters. Throughout, the key tenets of multidomain strategic theory commonality, opportunity presented by asymmetric tactics, primacy of technology, and inevitability of third parties in play shine through as consistent themes. He first introduces irregular warfare itself, comparing it with limited war, hybrid war, gray-zone conflict, gunboat diplomacy, and other similar, perhaps popularized terms that fulfill his fundamental criteria for *irregular*. For Klein, irregular warfare amounts to any multidomain strategy that does not involve conventional warfare, where the end result is won by more than military force alone. This point is important and one of a few golden threads through the work; the lessons from recent history regarding counterinsurgency, maintaining political will, guerrilla wars, and great power competition all apply in irregular warfare and in the space domain. It is in these early chapters that Klein's key argument that "space is not special" starts to become clear. Although space is not a new domain, theory can be applied to it as well as any other domain. This makes the work accessible to students of military strategy who find themselves attempting to navigate the application of operational art to the space domain.

Klein makes the assertion that a state's space strategy will probably align with its other multidomain strategies, which are fed by the state's politics and culture. Actions in space are unlikely to be strategically decisive on their own, but their impact may have strategic consequences. This is one area where Klein is able to describe the application of indirect warfare theory to the space domain, and he does so convincingly. Irregular warfare in space lends itself to cumulative strategies of small, non-decisive action, which prevents an overall victory. This highlights the asymmetric opportunity of a small space force and also the intractable nature and impact of time on irregular strategy, both of which are compounded in space domain conflict.

Chapter 3, arguably one of two key sections for space operations practitioners, discusses small space wars and the operational art of conducting irregular space warfare. Klein asserts that command of space—analogous to both command of the sea and control of the air—cannot be absolute but will be bounded temporally and spatially as well as often disputed. Key terrain across space, link, and ground segments are discussed. Klein also takes the opportunity to reintroduce celestial lines of communication—"those lines of communication in, through, and from space associated with trade, materiel, supplies, personnel, spacecraft, electromagnetic transmissions, and some military effects"—from his earlier work as a way to describe key terrain in space to be contested.[1] It is a fair argument that certain frequencies for communication or certain orbital regimes or planes are more valuable than others and that they will be contested. Klein discusses space control in terms of general versus local and persistent versus temporary—a valuable discussion, but one that left me wishing for a quadrant matrix as an accompanying figure to illustrate a space vignette fully.

In chapter 4, Klein also delineates how limited warfare or assertive activity short of conflict can still present challenges to space actors. Analogies with gunboat diplomacy are again well made and should give strategists thought when considering how to either assure access to space or coerce an outcome. A key argument introduced here and continued later is how space domain awareness—and its attribution of space action—is needed to reduce the gray zone that adversaries operate within during limited war. This argument offers one of the book's more immediately and practically applicable ideas, reinforced in chapter 8 with Klein's framework that recognizes space attribution as a process; however, it deserves even further exploration than this book provides.

Chapters 5 and 6 introduce lawfare—"the intentional distortion and misuse of legal regimes for competitive advantage"—and commercial risks and opportunities (91). Klein demonstrates how adversaries already have lawfare within their arsenal and how it is likely to also be employed in space. Borrowing from naval irregular warfare, he discusses space privateering and piracy, where the probability of the former—the pillaging and taking of "prizes" such as space capabilities or services with the authority of the government or other licensor—is well argued. Yet, the possibility of space pirates—who act outside of

1. John J. Klein, *Space Warfare: Strategy, Principles and Policy* (Abingdon, UK: Routledge, 2006), 51.

the law—seizing such prizes, is perhaps a step too wide on the cone of plausibility. Setting the conditions for lawfare to be employed, he argues that commercial actors in space will drive the maturity of the space domain more than government actors. It is therefore incumbent on states to integrate key commercial elements into a hybrid space architecture, both to establish norms for space behavior in order to defend against lawfare and to exploit the opportunities and redundancies found within dual-use capability.

This latter opportunity from the commercial sector is further discussed in the context of space technologies in chapter 7. Klein offers that technology can provide deterrence by denial; any definitive action against a capability in space that can be mitigated through a hybrid redundancy potentially reduces the chance of the action at all, protecting sovereign capability. Klein then contends that, largely owing to the technologically driven context of space operations, the domain is inherently both offensive and predictable. A valid example is seen in the ways costs of launch forces prioritize ensuring payload capability over including defensive suites, whilst technology makes obfuscation difficult.

The book's second key element for the practitioner is the proffered 10 counterstrategies for irregular warfare in space. Here, Klein argues for education in irregular space warfare and then the criticality of maintaining political support and patience when in a prolonged, irregular conflict. He restates the importance of attribution through his space attribution framework, which creates a triad between space domain awareness, intelligence, and commercial elements. He argues the case for defensive measures and resilience in space and notes the need for a nonmilitary solution to irregular warfare, stating the importance of dispersal and concentration—that is, maneuverability—before work with commercial partners and allies. Klein's final point is to tie off a key thread that runs throughout his work: space is not special. There is no all-encompassing answer or rules to space strategy; there are just strategic guidelines for current strategists to contend with and apply.

Klein has made convincing arguments throughout. In what is a nascent but growing pool of academic literature, *Fight for the Final Frontier* is accessible to current military strategists and will help place space warfare thinking in the minds of multidomain planners. Yet whilst some of Klein's key strategic theories are well illustrated at a level accessible to the generalist, one or two clear and realistic space vignettes with more depth would help seat the book's offerings in the generalist strategy student's mind and therefore neatly into multidomain strategic education. Overall, *Fight for the Final Frontier* presents a good thesis. It deserves a place as essential reading for any military member engaged in professional military education or indeed any staff charged with operations, strategy, or capability development.

**Squadron Leader Mike Lambert, Royal Air Force**

***Warrior Diplomats: Civil Affairs Forces on the Front Lines***

Edited by Arnel P. David, Sean Acosta, and Nicholas Krohley. Cambria Press, 2023, 280 pp.

As the Department of Defense shifts its focus toward strategic competition, its temptation to simply leverage technological overmatch is real. In *Warrior Diplomats*, Arnel David, Sean Acosta, and Nicholas Krohley offer an anthology of nine chapters regarding the value proposition of military civil affairs forces within this new environment and how, at scale, the activities of these specialized service members inform military commanders—particularly in the human domain—at a fraction of the cost of the forecasted hardware procured for the Joint force.

Despite published Joint, Army, and Marine Corps doctrine, there currently exists no unified theory of civil-military operations, but instead an interdisciplinary—and messy—body of work from sociologists, historians, political scientists, and strategists. The editors and authors of *Warrior Diplomats*, however, are largely operators, seasoned and exposed to the value of civil reconnaissance. David is a colonel in the US Army, Acosta a senior noncommissioned officer, and Krohley a US government adviser, all of whom hold experience operating within and publishing about the human domain. The authors of the chapters include civil affairs professionals from the active and reserve components, US Army, US Marine Corps, and British Army. Throughout the book, the authors challenge their field to know their worth and do better.

The term *warrior diplomat* used throughout the book stems from the civil affairs tradition of many of the authors and speaks to the military's role in engaging and influencing people as well as battlefields. The warrior, exposed to contested terrain, must take acceptable risk in pursuit of operational outcomes, while the diplomat must act prudently and discreetly with foreign counterparts. The Joint force is asked to appreciate the nuance of geopolitics for the coming struggles, but it is important to remember that all politics—even geopolitics—is local. To that end, warrior diplomats, through civil reconnaissance, provide the commander a more granular understanding of the human networks and communities which the United States seeks to influence.

Over nine chapters, the authors lament the ad hoc structures built over the previous decades to address commanders' demands in that moment but hold that the wrong lessons may be learned from strategic failures by focusing only on technology as the remedy. While the authors do not challenge the Joint force's need to adapt and modernize, they posit a critical weakness is the inability to understand ground truth in areas of geopolitical importance borne of a lack of investment engaging at lower levels. Further, the Joint force must address this vulnerability through systemic change.

In recent years, the services have been divested of many of their civil affairs forces. Whether this divestment is due to policymakers shifting the focus of resources toward technological change or to their fundamental misunderstanding of civil affairs' value proposition, the authors do not claim civil affairs is without room for improvement. Instead, the book begins by communicating the value of civil affairs forces using historical and recent examples then suggesting ways to optimize civil affairs and evolve beyond the current structure.

The book first offers a discussion of the strategic environment and the new great game, resulting from a world disaggregating beyond even the bipolarity of the Cold War. This disaggregation makes the application of standard geometric models of the international state of play difficult if not irrelevant, specifically because these models do not adequately account for localized details. This leads directly to a discussion of operating in the gray zone below the state of open conflict and the opportunities available to the state able to leverage information about the populations in question. In the gray zone, presence matters, relationships shift, and optimization is difficult. Warrior diplomats play a role as persistent partners, mapping local networks and providing continuous feedback to operations.

The discussion of the human domain balances cognitive and emotional models with historical context and strategic documents. Through this chapter, the authors remind the reader that influence over the population, the often-disregarded point of Clausewitz's trinity, requires an appreciation of both how people think and feel. The described relationship of network science is similarly academic as it relates to the discipline of civil reconnaissance cultivated in civil affairs manuals. Expanding on these models, Acosta challenges readers to elevate their staff work by "cancelling the crosswalk" matrices (the example given is the PMESII/ASCOPE matrix—political, military, economic, social, information, and infrastructure domains interwoven with areas, structures, capabilities, organization, people, and events) that equate to checking boxes rather than engaging in deep, meaningful analysis of populations relevant to commanders' decisions.

The messiness of these theories, however, is made salient with a relevant case study from central Africa's Lake Chad Basin, wherein forces managed to integrate multilateral humanitarian assistance and counterterrorism operations. The simultaneity of these activities, given the nature of influencing populations in under-governed spaces, may seem as necessary as it is novel to the staffer negotiating military authorities with higher headquarters. The authors then illuminate opportunities to optimize and improve with chapters on integrating civil affairs forces across the US Army (active and reserve components, conventional and special operations forces), across the Joint force (US Army and US Marine Corps), and across US Allies and partners—specifically discussing civil-military cooperation in the NATO Alliance—to build a global civil-military network.

*Warrior Diplomats: Civil Affairs Forces on the Front Lines* is, then, not a collection of war stories but a compilation that presents another paradigm for strategic competition beyond and complementing technological overmatch through its discussion of the value proposition of civil affairs forces moving forward. It leverages relevant examples of civil affairs actions during Operation Enduring Freedom–Philippines and the operation of the Danab Brigade in Somalia, but these inform the theories presented. Given the lack of exposure to civil affairs experienced by so many in the Joint force—neither the Air Force nor the Navy have designated civil affairs forces—*Warrior Diplomats* provides insight beyond what the practitioner might glean by simply reading doctrine. Current civil affairs forces may parochially appreciate the book insofar as it validates any thoughts they may have around organization and optimization. Even so, the layperson likely benefits more so with a broadened understanding of the tools available to the Joint force as it navigates the changing strategic environment.

**Lieutenant Colonel Robert Newton, USAF, PhD**

***Deter, Disrupt, or Deceive: Assessing Cyber Conflict as an Intelligence Contest***

Edited by Robert Chesney and Max Smeets. Georgetown University Press, 2023, 301 pp.

There is an old parable about a group of blind men encountering an elephant for the first time. They try to determine what the animal is through touch but are each able to touch only part of the elephant—its trunk, its ear, and its side. From their limited perspective, they determine what they have encountered—one thinks the elephant is a snake, another a fan, and the third, a wall. This same theme applies to the analysis of cyber in *Deter, Disrupt, or Deceive*, edited by Robert Chesney and Max Smeets. In examining offensive cyber operations, each editor finds comparisons based on their own understanding and offers solutions. The articles are well-researched and documented but lack any broad connection to an overall cyber operations thesis.

The editors ask contributors to frame cyber conflict as an intelligence contest—or "statecraft pursued through the means and methods traditionally associated with intelligence agencies"—before examining state and nonstate actor policies (5). Integrating all cyber conflict possibilities with such a narrow scope is a difficult task, even for someone like me, despite my career in intelligence. Still, the book provides interesting reading for anyone involved in cyber or intelligence operations.

In the first section, contributors analyze the theory and concept of intelligence contests and cyber operations. The underlying insight suggests that some cyber operations fit into this framework, but the perspective is focused on strategic contests, which support the ends of national policy, rather than intelligence missions, which are the means to achieve the ends. In the first chapter, Joshua Rovner outlines the book's central thesis, which demonstrates the five elements of intelligence contests: collect more information than an adversary; exploit information for practical gain; undermine adversaries' morale, institutions, and alliances; disable opponent intelligence capabilities; and pre-position collection assets for the future. Rovner's analysis of historical precedents spanning England and Spain in the late 1500s to the Cold War yield additional thoughts referencing the difficulty in using intelligence gains and a demand for secrecy in intelligence. The various authors discuss how these elements apply, but like the blind men, they are limited in their perspective to provide broader insights by viewing cyber operations through the lens of an intelligence contest.

The first six articles build a United States cyber operations perspective using the published national cyber strategy. Michael Warner starts the arguments by stating intelligence functions as a secretive support activity rather than a cyber end. The articles then address challenges between US Code Title 10 detailing military operations guidelines, and Title 50, which addresses intelligence collection difficulties in conducting covert cyber operations; and the United States' management of past cyberattacks.

Each article varies the approach slightly, but the common theme suggests cyber operations that focus on intelligence collection as operations are too difficult to manage and execute. The difference between intelligence collection and operations is that the former prepares for future conflict while the latter generates current or future effects. Cyber difficulties emerge as large operation secrecy, the technical scope needed to create effects, and deterrence model vagueness. Overall, the first section is interesting, but it highlights the need to further examine challenges in the US cyber model.

The next section addresses cyber internationally through China, Russia, and the United Kingdom. A retired People's Liberation Army officer submits the Chinese perspective on cyber operations as the defense of China's ideology. The author, Lyu Jinghua, suggests China's cyber aims to grow the country without physically destroying adversary assets constitutes legitimate cyber usage. This varies greatly from the international stance that economic cyberattacks such as stealing corporate intellectual property are as harmful as physical attacks.

Valeriy Akimenko and Keir Giles' article on Russia's approach to cyber activity contends that its current cyber operations mindset is an extension of Russia's long-term information operations. The case of Vasili Mitrokhin, a KGB defector who provided the UK's intelligence agency MI6 with intelligence files that exposed Soviet agents, is referenced as demonstrating how Russia has always defended its ideology against Western influences by any means necessary. Russian operations based in the GRU, an intelligence directorate, and the FSB, a state security agency that emerged from the KGB, show the national emphasis on continuing information warfare approaches.

Moving from adversarial nations to the UK, the philosophy shifts to protection rather than exploitation. Unlike adversarial nations but similar to the United States, the UK publicly acknowledges its cyber efforts center on the Government Communications Headquarters (GCHQ) intelligence hub. The section shows how other nations link intelligence contests and operations without losing the capacity to generate cyber effects.

The book concludes with nonstate actors. Nonstate actors typically imply terrorist organizations, but in the book, it refers to contractual parties working for the government in an intelligence capacity and other parties operating within the cyber environment. These parties have emerged due to the US government's general lack of cyber expertise. One key example, referenced in Lyu Jinghua's article, was American cybersecurity firm Mandiant's government-funded Chinese research. This government funding led China to conclude the Mandiant report constituted an ideological attack even when presented as pure research. The article demonstrates how government-funded cyber actors and government cyber action gaps will become inseparable in managing accountability. Thus, any action a private actor takes may be attributable to the US government. These discussions carry over to other state actions, such as use of social media by the Internet Research Agency (IRA) in St. Petersburg, Russia, to influence the 2016 presidential elections. The remaining discussion then addresses when contracted intelligence assets become official government action and whether those lines can be drawn effectively.

One clear gap in the book's analysis was in its technical knowledge concerning current cyber operational capabilities. The comment appears multiple times that cyber is more appropriate for intelligence as technical access lacks connections to physical effects. The 2008 Turkish pipeline explosion, Stuxnet, and multiple Ukrainian power outages are the most common physical examples of cyber effects. The 2014 Target hack shows where an infiltration via network access given to a vendor in charge of a physical system—the refrigeration, air conditioning, and heating system—led to financial results. Growing trends in smart houses, integrated grids, and Wi-Fi everywhere show where initial cyber effects could drive or support integrated actions. Those integrated actions currently match Russia's information warfare plans, whereas China remains focused on economic growth. Failing to address these points means authors may not have fully considered the operational effects possible through cyber.

Overall, *Deter, Disrupt, or Deceive* summarizes some old arguments in a new format, updates the packaging, and presents the same solutions. The various authors do not reach an agreement on whether cyber should be considered merely an intelligence resource or a strategic policy tool. Lacking a conclusion is emblematic of the cyber field as a whole: the areas reachable through cyber grow daily, and no one agrees on the perfect approach. The central thoughts examined were scaling operations, maintaining secrecy, analyzing other nation's strategies and civilianizing cyber functions. The answer likely lies somewhere in between; however, continuing to analyze the issue from only one perspective—identifying one part of the elephant, so to speak—will likely not move the debate forward. Still, I would recommend *Deter, Disrupt, or Deceive* to anyone who has been exclusively on either the intelligence or operations side of cyber for ideas in eventually bridging the gap with solid strategies supported by policy.

**Dr. Mark T. Peters II, Lieutenant Colonel, USAF, Retired**

***Outsourcing National Defense: Why and How Contractors Are Providing Public Services***
Thomas C. Bruneau. Lynne Rienner Publishers, 2023, 167 pp.

Thomas Bruneau's *Outsourcing National Defense* wants to set the record straight on DoD contracting. Bruneau, professor emeritus at the Naval Postgraduate School, oversaw contractors as chairman of its national security affairs department and director of its Center for Civil-Military Relations, eventually becoming a contractor himself. Early in the book he highlights that contracting makes up an enormous part of the DoD budget but is an understudied topic among scholars. Several studies dealing specifically with private military and security contractors exist, but such contractors are just one part of a multibillion-dollar industry. The book is therefore both an initial study of DoD contracting and a call for more academic scrutiny on the topic.

Bruneau modifies an existing civil-military relations framework to understand the degree to which the Defense Department successfully uses contracting to get results. The factors he examines include the coherence of the DoD's strategy overall, the level of education and training of those who award and monitor the contracts, the implementation of the contracts, the level of oversight by Congress, and the usefulness of the Federal Acquisition Regulation (FAR)—the set of regulations and authorities most often used for DoD contracting.

Bruneau broadly applies the framework to two security challenges—or what he calls "strategies"—that the United States has faced in the past 25 years: the Global War on Terror, specifically Iraq and Afghanistan, and great power competition with China. He argues that each demanded different requirements from contractors. While the war on terror drove demand for expeditionary contracting that supported the war effort abroad, great power competition requires contractors to provide cutting-edge technology. As the timelines of these two strategies overlap, the large number of contracts involved are often not always clearly demarcated as falling under one or the other. Yet, Bruneau makes a compelling enough case that these strategies should be treated separately in terms of contracting, and his analysis benefits from isolating two different lines of effort at least in theory, even if in practice such a distinction is less clear.

Bruneau reaches several broad conclusions in his book. The first is that a lack of overall strategy in the war on terror drove an increased dependence on contracting to support the military's operations abroad. Simultaneously, the Defense Department did not know how to use contractors in the most efficient way. For instance, the DoD staff in charge of monitoring contracts to combat waste, fraud, and abuse were often unable to travel to the area of operations to personally monitor the contracts' implementation for logistical and administrative reasons, including the overwhelming amount of paperwork involved along with the security risk. Consequently, as contracting abroad expanded, the Department was increasingly unable to oversee it efficiently. While the withdrawal from Afghanistan and reduced presence in Iraq lessened the number of contracts, the issue was never fully addressed. Bruneau cautions that another expeditionary conflict could easily replicate those dynamics of inefficiency.

Bruneau's other conclusions focus on defense contracting more broadly. He asserts that policymakers should develop strategies that include contracting since it makes up such a large part of the DoD budget and underpins military operations and the delivery of new technologies. For the latter case, he contends that FAR is not ideal for acquiring new technologies compared to another contracting framework, Other Transaction Authorities (OTAs), due to the latter's flexibility. OTAs have delivered significant results for the Defense Department, such as helping develop the COVID-19 vaccine. Still, very few contracts use OTAs compared to the FAR, so there are lost opportunities for the Department to acquire new technologies and compete successfully in great power competition.

How the Department of Defense treats the staff that manage contracts also matters. Bruneau points out that the Department does not use OTAs as much as it should because the staff who award and oversee contracts are poorly compensated and have limited prospects for career advancement. The existing structure offers few rewards for eschewing the FAR in favor of OTAs and presents potential consequences for one's career if they take a risk by not using FAR and do not succeed. He therefore argues that DoD personnel need a more effective incentive structure to pursue contracts that deliver new and better technologies.

The necessity for strong oversight, especially by Congress, is a major theme in Bruneau's book. He argues that the Defense Department often struggles to change without external pressure. In the war on terror, the Department resisted congressional oversight over contracting, even as lawmakers documented waste and recommended meaningful improvements. The most significant improvements to contracting for both the Defense Department and the Intelligence Community (IC) came after intense congressional monitoring and recommendations.

Bruneau's arguments and policy recommendations are compelling, but he is often limited by his sources and his access to information. This is not the fault of the author: few academic sources deal with the topic of contracting, and information about contracting from the Defense Department and Intelligence Community are frequently classified on the government side and proprietary on the industry side. Objective reports from the government, including the Congressional Research Service and Government Accountability Office, are in short supply. Bruneau conducted interviews with government officials and contractors to help fill in the gaps, but because contracting is ultimately such a complex and occasionally opaque subject and available information limited, he must resort to roundabout methods to reach his conclusions. For instance, he indicates that many problems in contracting by the IC were addressed because of a lack of reports and scrutiny after 2014. Yet these shortcomings reflect more on the quality of information currently available to researchers than on that of Bruneau's analysis itself.

As *Outsourcing National Defense* offers one of the first academic studies to tackle a topic as broad and complex as DoD contracting, there is much to build on. For instance, discussions on OTAs, contracting in Afghanistan and Iraq, and congressional oversight of contracting could easily fill books in their own right. Contracting in Intelligence almost certainly deserves its own study, as Bruneau's main focus is the Department of Defense as a whole rather than the IC, which spans multiple parts of the government. Bruneau and subsequent scholars should also seek to develop frameworks of analysis that are suited to the peculiarities of contracting, as the adapted framework he uses here may not be suitable for future studies.

This book is recommended not only for practitioners and scholars working on most elements of US national security, but also for those interested in contracting. Bruneau makes the point that contracting is so fundamental to how the Defense Department operates that a reasonable understanding of how it works is key to recognizing how the military approaches everything from counterterrorism abroad to technological advancement at home. Because the Department is especially reliant on contracting, scholars and policymakers focused on other parts of the US government or foreign governments may not find that all the conclusions apply to their context.

In all, *Outsourcing National Defense* is not without its shortcomings due to limited access to information, but it addresses an enormous gap in the scholarly understanding of US national defense and lays a foundation for future work on defense and intelligence contracting.

**Marcel Plichta**

***Blown to Hell: America's Deadly Betrayal of the Marshall Islanders***
Walter Pincus. Diversion Books, 2021, 416 pp.

Popular histories of American nuclear weapons testing commonly tend toward the Manichaean, neatly dividing that period of Cold War history between perpetrators and victims. In *Blown to Hell: America's Deadly Betrayal of the Marshall Islanders*, Walter Pincus rejects such a simplistic narrative, instead weaving a more intricate tale of the complex moral and technological decisions made by the United States during the early atomic age. The resulting work justifiably casts the people of the Marshall Islands, that small island nation in the Western Pacific, as victims of atmospheric nuclear weapons testing's literal and metaphorical fallout. Yet it simultaneously paints a very human picture of those who participated in nuclear weapons testing, from the scientists who underestimated the yields of prototype weapons, to the medical doctors who devoted their lives to the health of those affected.

Though not a credentialed historian, Pincus comes with his own pedigree, having been among *The Washington Post* staff who won the 2002 Pulitzer Prize for national reporting for its coverage of the war on terrorism.[1] Moreover, he has deep experience as a national security journalist, having reported for the *Post* from 1966 until 2015. Indeed, he traces his own interest in nuclear weapons testing's effects upon Pacific Islanders to his earliest days as a journalist, reinforced by a 1974 visit to the Marshall Islands. Pincus' professional background manifests itself somewhat jarringly in the more distinctive writing style of *Blown to Hell*'s later chapters, given their more contemporary focus; yet his grasp of the subject matter remains evident throughout the book.

Pincus divides *Blown to Hell* into two halves, each arranged chronologically. The first half, dubbed "The First Tests," traces American nuclear weapons testing from the Manhattan Project to Operation Castle in 1954. The second half, "Long-Term Problems," picks up in the immediate aftermath of the Castle Bravo shot—the March 1, 1954, test of a thermonuclear weapon at the Marshall Islands' Bikini Atoll, which to date remains the highest-yield nuclear weapons test in American history—and recounts the US government's decades-long inconsistent treatment of the Marshallese following the irradiation of their homeland.

Pincus' use of Castle Bravo as the book's narrative focal point is not without reason, given that test's very real consequences for the Marshall Islanders' health and ability to return to their homeland; yet it comes at the cost of eliding discussion of subsequent

1. "Staff of *The Washington Post*," Pulitzer Prizes (website), 2024, https://www.pulitzer.org/.

nuclear weapons tests in the Pacific. Indeed, Operations Redwing (1956) and Hardtack I (1958) pass entirely unmentioned, leaving the reader with the mistaken impression that testing at Enewetak and Bikini Atoll ended with Operation Castle, and forgoing the opportunity to more closely examine the process by which the US government weighed the Marshall Islanders' welfare against the competing demands of national security—itself a major theme of the book.[2]

The greatest strength of *Blown to Hell* is its ability to put a human face on those involved in nuclear weapons testing. Despite his evident sympathy for the Marshallese whose home islands were irradiated to the point of being uninhabitable, Pincus amply demonstrates that the scientists, military personnel, and bureaucrats responsible for conducting atmospheric nuclear weapons tests in the Pacific between 1946 and 1962 were operating at the limits of contemporary scientific comprehension.

For example, much detail is given regarding pioneering efforts to decontaminate target vessels after the second "Baker" shot of Operation Crossroads—the pair of nuclear weapons tests which in 1946 first displaced the Marshall Islanders from their home at Bikini Atoll—bathed its target vessels in irradiated seawater. Similarly, Pincus raises the important point that in 1954, scientists expected that Castle Bravo's yield would be six megatons, not the 15 that occurred, and that both the volume and the geographic dispersion of the resulting fallout were consequently far greater than their plans had accounted for.

But in addition to the islanders themselves, the author displays evident sympathy for those Atomic Energy Commission scientists and medical professionals who, like Dr. Robert A. Conard, devoted their professional lives to the Marshall Islanders' well-being notwithstanding their own government's role in the conduct of such tests. *Blown to Hell* thus yields a complex and multifaceted picture of the interactions between the US government and the Marshallese during and after the era of weapons testing.

That said, a significant defect of *Blown to Hell* lies in the inconsistency of its sourcing and argumentation. Although Pincus draws upon a diverse body of evidence, this does not uniformly speak to the US government's treatment of the Marshall Islanders. For example, fully 14 of the book's 41 chapters concern Operation Crossroads. Yet most of the content of those chapters concerns Joint Task Force One's planning and execution of the tests, with the Bikinians' evacuation and subsequent repatriation receiving comparatively short shrift—likely the consequence of the author's heavy reliance upon US government sources. Pincus likewise describes in engaging detail the task force's pioneering decontamination of Operation Crossroads' target vessels but does not examine how or whether the lessons learned from that effort might have informed projections on the probable effects of fallout upon the Marshall Islands during subsequent tests. The result is a narrative that is rich in incidental detail, but one which neglects to answer the

2. T. R. Fehner and F.G. Gosling, *Atmospheric Nuclear Weapons Testing, 1951–1963, Battlefield of the Cold War: The Nevada Test Site*, vol. 1 (Washington, DC: Department of Energy, September 2006), https://www.osti.gov/.

question as to how the US government failed to predict the long-term consequences of atmospheric nuclear testing.

The problem of argumentation repeats itself, in a different guise, in the second half of the book. Pincus is at his most engaging as a writer when describing the plight of the *Lucky Dragon #5*, the Japanese fishing vessel at the center of international controversy when in 1954 its crew was accidentally exposed to radioactive fallout from the Castle Bravo shot. The author relates a compelling narrative grounded in the historical record, juxtaposing the maximalist positions adopted by the Japanese and American governments against the well-meaning efforts of scientists and medical professionals to ascertain what had happened to the fishermen and how to assist them.

Yet the book notably fails to tie the *Lucky Dragon* incident into the overarching history of the Marshall Islanders' treatment by the US government. For example, it misses the opportunity to examine why the Japanese case received so much more public and international attention than the plight of the Marshall Islanders, beyond the simple fact that the White House exercised greater control over the flow of information in the latter case. A more comprehensive study of the Castle Bravo test's human toll might account for the political necessity of keeping Japan on-side during the Cold War, or consider whether implicit bias played a role in the disparate treatment accorded to the "modern" Japanese and "primitive" Marshall Islanders. *Blown to Hell*, however, merely tees up such questions for other writers to address more fully.

Pincus' book, though an uneven and incomplete account of American nuclear weapons testing and its consequences, remains an engaging and accessible work of popular history, which generally succeeds on its merits. It convincingly demonstrates the devastating legacy of such weapons testing upon the Marshall Islanders to a degree best suited for readers with an introductory understanding of this chapter of Cold War history. The book has the particular virtue of illustrating the diversity of the US government's responses to unforeseen problems surrounding nuclear fallout, juxtaposing those who sought to preserve secrecy at all costs against those who, like Conard, committed themselves to the task of improving the Marshall Islanders' lives. Most importantly, Pincus effectively demonstrates that for the Marshallese, this chapter of history remains open as they continue to experience the physical and emotional consequences of nuclear weapons testing.

**Lieutenant Colonel John William Sutcliffe IV, USAF, PhD**

***The Military Legacy of Alexander the Great: Lessons for the Information Age***

Michael P. Ferguson and Ian Worthington. Routledge, 2024, 370 pp.

British Army Major General J. F. C. Fuller, a veteran of World War I and a profound contributor to the development of armored warfare, wrote extensively on military theory, history, and biography. In particular, Fuller found examples of ancient generalship pertinent to contemporary military affairs and wrote accounts of the lives of two famous ancient generals, Julius Caesar and Alexander the Great—works which demonstrate Fuller's acumen as both historian and military officer.[1]

Ian Worthington, professor of ancient history at Macquarie University in Sydney, and US Army Lieutenant Colonel Michael Ferguson, history doctoral student at the University of North Carolina–Chapel Hill, have combined forces to write a new book attempting to follow Fuller's lead and make the ancient art of war more accessible to a contemporary audience. Their work not only focuses on Alexander the Great's campaigns and leadership but also melds ancient history with contemporary events and concepts. Their goal was not to write another biography or military history of Alexander, but to highlight select examples of his career that resonate in the modern era.

Yet while the authors lay out a clear description of key elements of Alexander's life and career and mix in several succinct accounts of modern events, the book's dual approach never really unifies around their central intended theme. They do demonstrate how important studying Alexander's life is for today's military leaders, just not as effectively as could have been done. Their attempt to merge modern military and ancient history into a cohesive narrative misses the mark, primarily due to the bifurcated approach.

After an introduction, the authors begin with some background and biographical information, and then, in order to prepare the reader for appreciating the relevancy of Alexander's context, they discuss contemporary military issues in an effort to "offer the reader a deeper appreciation for, and perhaps connection to, the ancient world by showcasing flawed assumptions surrounding divergent trajectories of modern conflict" (34). After explaining the rise of Macedonia and the development of its army in the aftermath of the classical age of Greek warfare, the book turns to surveying innovation and modernization in the modern military, focusing on the notion of the revolution in military affairs, inaugurated in the post-Vietnam era. Three chapters on key Macedonian campaigns are followed by another on modern issues, then another section on Alexander's more distant campaigns, his leadership legacy, and his performance as a strategist.

The sections covering Alexander's conquest of Persia are excellent, with tactical and operational details, maps, and careful analysis using a mix of modern history and ancient sources. The maps are particularly useful in aiding comprehension. The chapters on more recent military events and concepts are not as effective, partly out of a need for brevity but also in the topical structure in which they are couched. This ancient/modern mix is the chief problem with the book; the attempt to connect the Alexander narrative overtly to contemporary events and ideas is rather strained at times, despite frequent use of the "like Alexander" clause. A better approach would have been to mix the modern and ancient factors topically within the same chapter—that is, by extended applicable contemporary passages interlaced within the Macedonian narrative. For example, when discussing reforms and the innovative organization of the Macedonian army, some of the description

1. See J. F. C. Fuller, *Julius Caesar: Man, Soldier, Tyrant* (London: Eyre & Spottiswoode, 1965); and *Generalship of Alexander the Great* (New Brunswick, NJ: Rutgers University Press, 1960).

of the post-Vietnam revolution in military affairs could have been more directly inserted, followed by a comparative section.

Additionally, although Alexander and the US military both campaigned in the Near East, Mesopotamia, and Afghanistan, little attempt was made at comparing the two, other than their shared challenge of confronting different cultures. A more robust examination of the geographic factors in warfare for both ancient and modern armies would have been fascinating. A stronger editing of the text, seeking to mix the two historical approaches, could have enabled the writing and scholarship to be more cohesive.

The authors' call for the careful study of history by modern military practitioners is eloquently aided by their clear writing styles and carefully measured flow of facts and data. The reader is not drowned in detail, nor do they suffer from confusion due to breadth. A succinct, clever conclusion by former US National Security Adviser Lieutenant General H. R. McMaster, himself a history PhD, was a striking way to finish the work.

A detailed book on Alexander's generalship in and of itself is a rich source of lessons learned, inspirational leadership, and brilliant innovation for a modern commander. What would make Ferguson and Worthington's work resonate better with a contemporary reader is if, rather than forcing snippets of modern campaigns into the narrative, its language, structure, and approach modeled more traditional campaign history—the kind of history written by military officers for military officers, using one voice instead of two. This is what makes Fuller's *The Generalship of Alexander the Great* (1960) so powerful for a military reader, and the *Anabasis of Alexander* by Arrian (c. 86–160 CE)—a general like Fuller—stand the test of time. A Landmark version of Arrian, modeled along the lines of *The Landmark Thucydides*, is now available as a wonderfully accessible account of Alexander for today's readers; it would pair quite nicely with Ferguson and Worthington's work and give it a powerful resonance with the distant past.[2]

Nonetheless, *The Military Legacy of Alexander the Great* would be a useful study for students of history or security studies and would make a good reading for professional military education.

**James M. Tucci, PhD**

2. *The Landmark Arrian: The Campaigns of Alexander*, ed. James Room and trans. Pamela Mensch (New York: Anchor Books, 2012); and see *The Landmark Thucydides: A Comprehensive Guide to the Peloponnesian War*, ed. Robert B. Strassler and trans. Richard B. Crawley (New York: Free Press, 2008).

### *The Coming Wave: Technology, Power, and the 21st Century's Greatest Dilemma*

Mustafa Suleyman with Michael Bhaskar. Crown Publishing Group, 2023, 352 pp.

*The Coming Wave* is a futurist nonfiction science and technology book by Mustafa Suleyman. Suleyman is the co-founder of two artificial intelligence (AI) companies, DeepMind and Inflection AI, and has held multiple AI development and policy positions throughout his career. *The Coming Wave* attempts to stand out among a multitude of emergent technology books written within the past year with its take on how an ensuing technological revolution will result in a far more dramatic impact on humanity than any other in history. Though it offers valuable insights, the book overstates the threat of AI and synthetic biology while proposing containment options that Suleyman admits are unrealistic to implement.

The foundational premise of *The Coming Wave* is that throughout history, there have been "waves" of technological advancement with reverberating effects that altered the course of human history. Suleyman delineates 24 previous general-purpose technologies that have indiscriminately diffused across the globe, with the 25th currently in progress. He argues that preceding waves ranging from the discovery of fire to the proliferation of the internet have not been as disruptive to human technological evolution as the impending wave, which combines AI and synthetic biology. A convergence of large-scale knowledge systems with genetic modification, as he proposes, will transform the world at an unprecedented pace and with far-reaching, irreversible consequences. Suleyman supports this claim by highlighting the effect economies of scale are having on the increased availability of these technologies. Specifically, he notes the relative ease of acquiring advanced genetic testing equipment that is enabling the establishment of hobbyist biological labs, akin to the early '90s tech sector garage startups. While still a well-intentioned niche market, these homegrown experimentation centers augmented by emergent AI systems could accelerate radical pursuits of human genome modification with potentially disastrous results.

In supporting the premise that the world is amid the next large-scale transformation, Suleyman thoroughly covers numerous examples of previous technologies expanding beyond their original intended use and being adapted for other purposes. This is being played out in the current wave through the widespread adoption and adaptation of large language models (LLM) for uses that promote knowledge discovery and application for both good and bad. The author posits that recent advancements in AI will follow an exponential trajectory, leading to a redistribution of wealth and power that could disrupt the existing geopolitical order in favor of small nation-states and nonstate actors. This redistribution would give ambitious actors the ability to not only fund but also rapidly develop and scale capabilities favoring their ideological use cases.

This background effectively establishes the foundation for Suleyman's argument for containing the impending technological wave and limiting its potentially disastrous effects. Yet Suleyman immediately undermines his efforts to rally humanity to his cause by highlighting that previous technological containment has largely failed. One example he provides is the Ottoman Empire's thwarted attempt to restrict the effects of the printing press, specifically to ban Arabic writing.

Acknowledging the complexity of the task at hand, the author primarily focuses on topics that present a worst-case scenario and neglects substantive discussions on the positive aspects of the technology. For example, his proposed vision of deep surveillance states or an "East India Trading Company" consolidation of corporate influence, while plausible, is representative of a superficial omission of incremental adaptation of these technologies as an opportunity for divergent outcomes. Ultimately, Suleyman's attempts to include counterarguments to the overly pessimistic stance are not as impactful as the arguments for a worst-case scenario and, in the end, do not provide enough balance to overcome the alarmist tone. These views also neglect to support a relevant way forward.

The author proposes 10 steps to contain the rapid expansion of technology, ranging from technological safeguards and government regulation to cultural changes and large-scale movements. Most, if not all, of these steps are grandiose and largely unattainable because of the bureaucracy and cost associated with implementing them. The author rightly acknowledges the near impossibility of such an effort, but admirably persists in his recommendation anyway. While the steps for containment have solid support, they should not be viewed as the ultimate guide. Instead, as he mentions in chapter 13, these steps should serve as a catalyst for further conversation.

As a thought experiment based on the content in the book, I asked Google's latest LLM, Gemini Advanced, if it agreed with the arguments presented in the book. Its output: "It's difficult to give a definitive yes or no to whether I agree fully with *The Coming Wave*." It then explained why it could not fully agree or disagree: "I don't form my own beliefs or opinions in the same way a human does. I process information and provide responses based on patterns and probabilities in the data I've been trained on."[1]

These responses illustrate two concepts from the book. The first is an attempt at technological containment by putting guardrails in place to control the output from LLMs. The second is the drive for corporate-aligned interests and protectionism by preventing copyright material from being used. There is movement in the right direction, as Suleyman states, and his steps to containment are a starting point. Ultimately, the author's assessments, based on research and personal experience, are well-intentioned. But the future is incredibly difficult to predict, and this next wave as he describes it may or may not come to pass.

The book tends to be a bit repetitive throughout and seems to emphasize the main points with excessive reasoning. This over-justification tends to be monotonous and can read as a desperate attempt to support the book's main stance. This does little to help Suleyman overcome the tendency common among leaders to reject narratives seen as negative—what he calls "pessimism aversion"—which he seeks to avoid. Furthermore, as Suleyman comes primarily from an AI background, detailed discussions of synthetic biology are missing from the text, which can at times cause a lack of focus and distraction when the subject is briefly reintroduced.

Still, Suleyman presents solid and extensively researched concepts that provide an ideal starting point for discussing the proper implementation of this new technological frontier. While *The Coming Wave* presents valuable insights, it ultimately tends to be overly alarmist and is unlikely to attract a wide audience outside of technologist communities.

**Captain Brad Worley, USAF**

1. Text generated by Gemini, Google, February 4, 2024, https://gemini.google.com/.

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