SYM-AM-23-093

Excerpt from the Proceedings of the Twentieth Annual Acquisition Research Symposium

Acquisition Research:
Creating Synergy for Informed Change

May 10–11, 2023

Published: April 30, 2023

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

The research presented in this report was supported by the Acquisition Research Program at the Naval Postgraduate School.

To request defense acquisition research, to become a research sponsor, or to print additional copies of reports, please contact any of the staff listed on the Acquisition Research Program website (www.acquisitionresearch.net).

Acquisition Research Program
Department of Defense Management
Naval Postgraduate School

Asymmetries and their Potential for Enduring Advantage

Todd Harrison—is the Managing Director of Metrea Strategic Insights. Prior to joining Metrea in May 2022, Harrison was a senior fellow and the director of Defense Budget Analysis and the Aerospace Security Project at the Center for Strategic and International Studies (CSIS). He joined CSIS from the Center for Strategic and Budgetary Assessments (CSBA), where he was the senior fellow for Defense Budget Studies. At both CSIS and CSBA, Harrison authored numerous publications on trends in the defense budget, military space systems, threats to space systems, civil space exploration, defense acquisitions, military compensation and readiness, and military force structure, among other topics. Before joining the think tank community, Harrison worked as a consultant to Air Force Space Command while at Booz Allen Hamilton, as a program and product manager at space startup AeroAstro Inc., and as a management consultant at Diamond Cluster International. Harrison served in the U.S. Air Force Reserves and is a graduate of the Massachusetts Institute of Technology with both a BS and an MS in aeronautics and astronautics. He is currently a non-resident senior associate at CSIS, a member of the National Security Space Association Board of Advisors, and an adjunct faculty member at the Johns Hopkins School of Advanced International Studies where he teaches classes on the defense budget and military space systems.

Abstract

The 2022 National Defense Strategy calls for a renewed focus on identifying and leveraging asymmetries to better direct investments in ways that will yield enduring military advantage. The pursuit of asymmetric advantage, however, is not new and has been part of military strategy for centuries. This paper—a preview of a more comprehensive forthcoming paper from Metrea Strategic Insights—uses examples from nature and military history to develop a framework for assessing the potential of an asymmetry to provide enduring military advantage. The framework consists of five key factors: how immutable the source of the asymmetry is, how difficult it is to copy or counter, at what level of effect the asymmetry is anchored and how applicable it is across the spectrum of operations, the degree to which it builds on other underlying asymmetries, and how well it scales. The paper applies the framework to assess three example areas of competition that are often touted as potential asymmetries: ubiquitous ISR, hypersonic weapons, and commercial innovation. The paper finds that asymmetries vary significantly in their ability to endure, the degree to which they maximize leverage, and their potential to scale effects exponentially. The framework presented can help inform which asymmetries are best aligned with defense strategy and how defense resources can be most effectively and efficiently applied.

Introduction

The pursuit of asymmetric advantage has long been recognized as a critical factor in shaping the outcomes of strategic competition. While asymmetries are abundant, finding asymmetries that can produce significant and enduring advantages can be challenging. More than two thousand years ago, the Germanic chieftain Arminius leveraged asymmetric advantages in his choice of terrain and operational decision making to defeat a better armed and numerically superior Roman force (Goulding, 2000). More recently, Ukrainian forces have used a variety of asymmetric means to withstand a much larger Russian force, leveraging access to Western weapons, intelligence, and financial resources and having a more determined and defiant populus, to name a few. While the technology and character of war has profoundly changed over the centuries, the fundamentals of finding and leveraging asymmetric advantages remain relevant to the strategic discourse today.

The Third Offset Strategy, which came to prominence in the second term of the Obama Administration, was based largely around the idea of finding and exploiting asymmetric advantages. The "offset" in the strategy's name refers to previous efforts in the 1950s and 1970s to offset the Soviet military's quantitative advantage using asymmetric means. In the 1950s, the United States exploited its asymmetric advantage in nuclear weapons, fielding a nuclear force capable of delivering a massive retaliatory strike sufficient to deter Soviet aggression. The 1970s offset strategy relied on an advantage in precision strike to offset a numerically larger Soviet conventional force. This asymmetry had the added advantage of luring the Soviets into a costly arms race, where they needed to either invest large sums of money in modernization to keep pace with the qualitative advantage of U.S. forces or build an even larger conventional force to overcome these advantages with mass. While the Third Offset arguably never fully congealed into a specific strategy, its basic premise was a continuation of the offsets pursued in the 1950s and 1970s. It sought to find and leverage asymmetric advantages in emerging technologies, such as artificial intelligence (AI), machine learning (ML), and autonomous vehicles, in combination with new organizational and operational constructs, to offset Chinese and Russian advances in conventional military capabilities (Gentile et al., 2021).

Current defense strategy seeks to exploit asymmetries in several ways. The 2022 National Defense Strategy says the military will use asymmetric approaches for deterrence, selectively share asymmetric capabilities with allies and partners, and leverage fundamental asymmetries in the American economy, culture, and system of government to "build enduring advantages" (DoD, 2022). Its predecessor document, the 2018 National Defense Strategy, cited the value of allies and partners as an "asymmetric advantage that no competitor or rival can match" (DoD, 2018). Moreover, the DoD's recently published *Technology Vision for an Era of Competition* says the Defense Department will "maximize our asymmetric advantages by partnering with the larger innovation ecosystem, from industry to universities and to laboratories, allies and partners" (Office of the Undersecretary of Defense for Research and Engineering, 2022). These strategy documents and the historical examples cited highlight how asymmetries can be a powerful tool to counter or offset the technological, numerical, or operational superiority of an adversary.

This paper is a part of a more comprehensive forthcoming capstone study by Metrea Strategic Insights that develops an overarching theory of victory for the United States and its allies and partners that is rooted in asymmetries. As an excerpt from that study, this paper presents a framework for identifying and evaluating asymmetries to better assess the military advantage they can provide and their potential to endure over time. It begins with an exploration of asymmetries in nature to develop an understanding of asymmetries from first principles and why they matter. It uses historical examples of asymmetries in military competition to highlight the factors that affect how enduring they can be, the degree of leverage they can provide, and their potential to scale exponentially. Based on these examples, the paper presents a framework for evaluating and comparing asymmetries. It concludes by applying the framework to assess example areas of competition that are often touted as potential asymmetric advantages.

Asymmetries in Nature

Symmetry can exist in many forms and to different degrees. An object can be symmetric top to bottom, left to right, or front to back. It can have translational symmetry, which means it appears the same if the observer moves from side to side. It can have rotational symmetry, which means the object appears the same if the observer rotates it about a central axis. A sphere is the most perfectly symmetric object in three dimensions, and we see many examples of sphere-like shapes throughout nature. The Earth, sun, moon, and many other celestial bodies in the macroscale universe appear spherical at a distance. As Frank Close writes in his book, *Lucifer's Legacy: The Meaning of Asymmetry*, "The fact that the entire cosmos has a common feature implies that there is something deeply encoded in the laws of nature that makes it like this" (Close, 2000, p. 13). The general shape of celestial bodies is a result of the gravitational force that attracted clumps of matter together over millions of years. While the gravitational force diminishes in proportion to the inverse square of the distance between two objects, it acts uniformly in all directions between all objects regardless of the orientation of the objects that are interacting.

Asymmetry is the lack of symmetry, and like symmetry itself, it is a matter of degree. Something can be symmetric in one way but asymmetric in other ways. Examining celestial bodies in the macroscale universe more closely reveals that they are not perfect spheres and are in fact asymmetric in many respects. The moon is covered in irregularly distributed craters, with many more on the side of the moon facing away from Earth (Jones et al., 2022). The Earth itself has irregularly shaped land masses, mountains, valleys, and polar ice caps, and it bulges slightly around the equator. The sun is a highly dynamic system with asymmetric eruptions of energy in the form of coronal mass ejections. These irregularities are the result of more complex interactions in nature which involve other forces that, unlike gravity, do not act uniformly in all directions. The electromagnetic force, for example, attracts objects of opposite charge and repels objects of like charge, and this is the dominant force at the molecular level governing how atoms come together to form the gases, solids, liquids, and more complex structures around us. Time is itself asymmetric because it only progresses in one direction. As observed by Sir Arthur Stanley Eddington and others since, the asymmetry of time leads to many other forms of asymmetry and irreversible processes, such as the fact that heat spontaneously flows from hot to cold and not the reverse (Eddington, 1948). Without these fundamental asymmetries in nature, the universe as we know it would have never sprung into existence. As one scientist notes, "In physics, to be symmetrical is to be immune to possible changes" (Livio, 2012). Asymmetry creates the potential for change—the power to shape, affect, and evolve.

At increasing levels of complexity in the natural environment, asymmetries become more interesting and consequential, and in some instances, they lead to distinct advantages. Louis Pasteur, in a paper on asymmetry at the molecular level, remarked that, "Life as manifested to us is a function of the asymmetry of the Universe and of the consequences of this fact" (Salam, 1990). At the microbiological level, relatively simple single-celled organisms like bacteria evolved to have asymmetric shapes and growth patterns at different phases in their life cycles. When some single-celled organisms divide, for example, the two parts are not identical. This allows for a "selective advantage" to accrue over time. Research has shown that organisms can use asymmetric division to purge damage found in individual cells, such as misfolded proteins, from an overall population. As one journal article notes, "by biasing damage segregation into one cell upon division, a relatively damage-free daughter enjoys higher fitness at the expense of the aging cell, thereby increasing the overall damage tolerance of the population" (Kysela et al., 2013). The asymmetry of cell division proves to be an enduring advantage in nature in part because it only progresses in one direction—once a cell divides and the advantage accrues, it cannot be reversed. Moreover, it is a self-perpetuating advantage because cells that divide asymmetrically are more likely to survive and propagate.

More complex forms of life can exhibit more complex forms of asymmetric advantage. The family of fish known as Flatfish (or *Pleuronectidae*), which includes Flounder, Halibut, and Sole, is perhaps one of the most peculiarly asymmetric animals to have ever evolved, as shown in Figure 1. Charles Darwin commented on this type of fish in *The Origin of Species*, noting that the advantage of their "flattened and asymmetrical structure" is evident by the fact that several species of this family are "extremely common" in the wild (Darwin, 1872, p. 240). The flatfish begins life as a typical fish with bilateral (left-right) symmetry, but as it grows and matures one if its eyes migrates from one side of the head to the other side. As a result, these fish spend most of their adult lives swimming sideways with both eyes on the same side of their head (Skeptic's Play, 2009). As Darwin notes, "the chief advantages thus gained seem to be protection from their enemies, and facility for feeding on the ground" (Darwin, 1972, p. 240).

Figure 1. A Peacock Flounder with Asymmetric Eyes.
(© cherylvb / Adobe Stock).

The brain also evolved to be asymmetric in both its shape and function. In his book, *The Master and His Emissary: The Divided Brain and the Making of the Western World*, Iain McGilchrist explores how the shape and function of the human brain evolved to be highly asymmetric. Like other animals, the human brain is divided into hemispheres, but it "appears to have been twisted about its central axis," with the left hemisphere wider towards the back and the right hemisphere wider towards the front (McGilchrist, 2012, p. 23). This asymmetry in shape also corresponds to an asymmetry in function that allows the brain to attend "to the world in two ways at once" (McGilchrist, 2012, p. 30). The left brain specializes in activities that require narrow and focused attention, whereas the right brain specializes in keeping track of the broader context of the environment and how one relates to that environment. McGilchrist goes on to explore how the asymmetric division of functions in the human brain manifests itself in society and culture (McGilchrist, 2012, p. 431).

Another asymmetry in nature that can have far reaching effects in human interactions is geography. Macroscale forces acting over millions of years, such as the movement of tectonic plates, volcanic eruptions, and erosion, created the oceans and the land masses humans inhabit. The geography of the Earth, and the access to resources it conveys, is a fundamental asymmetry among nations. Differences in geography mean that no two nations are alike in the resources available to them or in the interdependencies they share with other nations for trade, diplomacy, and culture. Nations vary greatly in size, climate, water and mineral resources, arable land, access to natural trade routes (e.g., rivers and oceans), and proximity to rivals. History has shown that these geographic factors directly influence the character of a nation, its economy, and the security challenges it faces (Diamond, 1999, p, 25).

Figure 2 illustrates some of the geographic and natural resource differences among the permanent members of the United Nations Security Council, as an example (CIA, n.d.). While these five nations enjoy comparable diplomatic status and have historically been major powers in the world, fundamental differences in their geography influenced how they evolved over time and the strategic position they find themselves in today. For example, both Russia and China have extensive land borders, which requires significant resources for ground forces and border defenses. While Russia has extensive energy resources in the form of coal and crude oil reserves, it has relatively little arable land, leading it to become a major energy exporter and food importer. China is relatively poor in energy and arable land (relative to its population and level of industrialization), and it is dependent on imports of both. The resource limitations imposed on China and Russia by nature incentivized each to adopt zero-sum, neomercantilist policies designed to make “asymmetric economic gains at the expense of competitors” (Ziegler & Menon, 2014). In contrast, the United States has friendly nations on its northern and southern land borders, large oceans protecting its coastlines to the east and west, and access to sufficient energy (mainly coal) and arable land. As a result, the United States has often had the luxury of choosing to engage with other nations when it is mutually beneficial and in accordance with its own values (Biden, 2021).

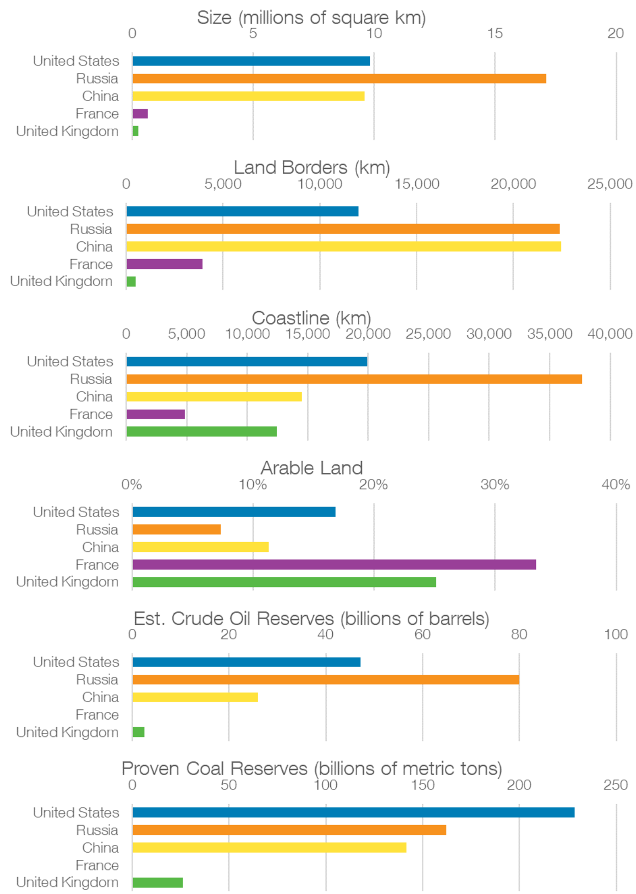

Figure 2. Selected Geographic Factors for the UN Permanent Five

As this discussion has shown, asymmetries play an important role in nature. They arise from the fundamental laws of the universe, and at the most basic level they are the result of imbalances and directionality in nature. Processes that are irreversible, from cellular division to volcanic eruptions, effectively “lock in” asymmetries and prevent nature from returning to an entropic path of decay toward absolute symmetry. Asymmetries that are advantageous in nature tend to be self-perpetuating, such as the selective advantage provided by the asymmetric division of functions within the brain. Moreover, it becomes evident from nature that asymmetries can work synergistically together over time to create an additive and, in some cases, exponentiating advantage. Asymmetries give us the ability to affect the environment around us, and to maximize those effects we must find ways to maximize the asymmetries that exist in relation to what we are attempting to affect.

Asymmetries in Military Competition

Military competition is often asymmetric in each party's perception of their relative standing. If adversaries shared the same assessment of their relative standing, the rational course of action for the weaker side would be to regroup and find a new approach rather than commit itself to a competition in which it is unlikely to prevail (Farley, 2012). What is often found in practice is a David versus Goliath situation where the weaker side (or the side that perceives itself to be at a disadvantage) pursues an asymmetric strategy. Rather than trying to match its opponent plane for plane or tank for tank, it instead finds ways to compete that its opponent finds difficult to match or counter. Over time, however, the stronger opponent will attempt to rectify this by negating the asymmetry and regaining the advantage. For this reason, asymmetries in military competition are often "transient phenomena" (Krajewski, 2012). This section presents historical examples of asymmetric strategies at three different levels of effects: the New Look (or the First Offset) at the strategic level; precision strike (or the Second Offset) at the operational level; and the improvised explosive device (IED) at the tactical level. These examples provide insights into the factors that determine how much advantage an asymmetry is likely to provide and how enduring that advantage is likely to be.

The New Look

World War II upended the world order in many ways. It left the British and French empires in demise, and it brought two of the most powerful militaries in the world, Japan and Germany, to their knees in unconditional surrender. This allowed the United States and the Soviet Union to quickly ascend as the world's two superpowers. Moreover, in the immediate aftermath of the war, the United States held a temporary monopoly on the most powerful weapon ever devised—the atomic bomb. The post-World War II period quickly became a struggle between the free nations of the West and the communist nations of the East, and the Korean peninsula became a focal point in this struggle. President Eisenhower took office in the middle of the Korean War and sought to quickly bring the conflict to a conclusion. During the presidential campaign of 1952, Eisenhower made clear that he viewed the Korean War as a grave error in U.S. foreign policy, saying "There is a Korean War—and we are fighting it—for the simplest of reasons: because free leadership failed to check and to turn back Communist ambition before it savagely attacked us." Later in the same speech he pledged to bring the war to "an early and honorable end" (Eisenhower, 1952).

As he worked to disentangle the U.S. military from the Korean War, Eisenhower recognized that the United States could not afford to match the Soviet Union in conventional forces or in prolonged proxy wars like Korea. The Soviet military maintained a much larger ground force, a necessity to defend its extensive and vulnerable land borders. Estimates at the time (which later proved to be misleading) suggested that the Soviets had 175 Army divisions that were "fully manned, fully armed, and combat-ready" (Bitzinger, 1989). This was roughly three times the conventional ground forces the United States and its allies possessed. Eisenhower believed the cost of matching the Soviets division for division would ultimately handicap the U.S. economy. Instead, he sought an alternative strategy that would "offset both the Soviet's advantage in conventional troops and their nascent nuclear arsenal" (Gentile et al., 2021, p. 9). This strategy—what became known as the New Look—was captured in National Security Council Paper 162 and later revised in NSC 162/2. In more recent years, this strategy has been referred to as the First Offset.

The New Look was based on the concept of massive retaliation—the idea that the United States would deter Soviet aggression at the strategic level by building a large and resilient nuclear arsenal that could survive a first strike and still deliver a devastating counterattack. It was rooted in the belief that "the only way to win the next world war is to prevent it" (Eisenhower, 1956). The strategy was particularly appealing at the time because it leveraged an asymmetric advantage the United States held in nuclear technology, and the cost of fielding and maintaining a nuclear capability for massive retaliation was significantly less than matching the Soviet military division for division. Moreover, the Soviets could not easily defend against a nuclear attack because it would require a level of air and missile defense technology that was not yet within reach.

By the end of the 1950s, however, Eisenhower's New Look came under increasing criticism. The Army struggled throughout the 1950s to adapt to the new strategy, with a failed attempt to reorganize into "Pentomic Divisions" designed to operate on a nuclear battlefield. The strategy also became more symmetric over time as the Soviet Union reached rough parity with United States in its own nuclear forces. Massive retaliation was no longer a credible threat to deter lower-level Soviet aggression once it had a secured second-strike capability of its own. What was needed, opponents of the strategy argued, was a more flexible set of options for how the United States could respond to aggression—what became known as the Kennedy administration's Flexible Response strategy (Gentile et al., 2021, pp. 10–11).

Precision Strike

By the 1970s, the buildup of Soviet nuclear forces had effectively eliminated the asymmetry the United States sought to exploit in the New Look. Nuclear parity made it possible to negotiate arms control treaties to limit the size of each nation's nuclear arsenal, and it created a stable deterrence posture (what became known as mutually assured destruction or MAD) that prevented a nuclear exchange. Under the first Strategic Arms Limitation Talks (SALT) treaty, the United States was limited to 1,054 Intercontinental Ballistic Missile (ICBM) silos and 710 Submarine Launched Ballistic Missiles (SLBM) launch tubes while the Soviet Union was limited to 1,618 ICBM silos and 950 SLBM launch tubes. The treaty did not limit bombers or the total number of warheads, and each side's nuclear forces remained more than sufficient to deliver a devastating second strike (Kimball, 2022). This rough symmetry at the nuclear level brought the focus of the U.S.-Soviet military competition back to conventional forces.

In the 1970s, the Soviet Union continued to have numerical superiority in its conventional forces. Moreover, the United States' elimination of the draft in 1973 made it more costly than ever before to field a force comparable in size to the Soviets (Comptroller General of the United States, 1978). Senior defense officials, particularly Defense Secretary Harold Brown, Undersecretary of Defense for Research and Engineering William Perry, and Director of Net Assessment Andrew Marshall, concluded that a new strategy was needed to offset the Soviet military's quantitative advantage and deter an armored assault across Europe—what later became known as the Second Offset (Gentile et al., 2021, pp. 12–13).

The idea behind the Second Offset was to shift the competition into an area where the United States would enjoy an asymmetric advantage: its ability to rapidly develop and operationalize innovative new technologies and operational concepts. As William Perry noted in congressional testimony, "Precision guided weapons . . . have the potential of revolutionizing warfare," and "greatly enhance our ability to deter war without having to compete tank for tank, missile for missile with the Soviet Union" (Gentile et al., 2021, p. 15). The strategy called for using precision guided weapons and advanced delivery systems (such as stealthy aircraft) in combination with innovative concepts of operation, such as Active Defense and AirLand Battle, to give the United States a qualitative advantage—a force multiplier that would allow a relatively smaller number of U.S. forces to defeat a much larger adversary.

The technologies and doctrine developed as part of the Second Offset were on full display in the 1991 Gulf War and later in the conflicts in Bosnia and Kosovo. These conflicts demonstrated the powerful effects that could be generated through the combined use of space systems, precision guided weapons, and stealthy aircraft, among the many other advanced weapon systems employed. The dramatic success of air power in these conflicts unwittingly exposed one of the weaknesses of precision strike—it is only an advantage if it is supported by precision intelligence. For example, several months into the Kosovo air war, Air Force commanders worried that they were running out of good targets and that it was becoming increasingly difficult "to find and demolish the dispersed Yugoslav troops and equipment that remain in Kosovo without unintentionally striking civilians who are often mixed in with them" (Harris & Graham, 1999).

China, Russia, and other potential adversaries took note of the asymmetric advantage the United States held and adjusted their own strategy, doctrine, and investments accordingly. As former Director of National Intelligence Mike McConnell surmised, adversaries like China "concluded from the Desert Storm experience that their counterapproach had to be to challenge America's control of the battle space by building capabilities to knock out our satellites and invading our cybernetworks" (Gardels, 2010). To counter the United States, China developed anti-access/area denial (A2/AD) capabilities, such as robust and integrated air defense networks and long-range ballistic missiles and cruise missiles, to keep U.S. forces at range. Both Russia and China developed a suite of anti-satellite (ASAT) capabilities, from direct-ascent ASAT weapons to satellite jammers and laser dazzlers, to disrupt American intelligence collection, navigation, and communications capabilities, making it harder to sense and coordinate actions (Johnson et al., 2022). And in parallel, both nations developed and fielded precision strike capabilities of their own, making the asymmetric advantage more symmetric.

Improvised Explosive Devices

When the United States went into Afghanistan in 2001 and launched its invasion of Iraq in 2003, it enjoyed numerous advantages over the Taliban and Iraqi military. While China and Russia were working to undermine the Second Offset strategy, the asymmetric advantage of precision strike continued to work well in Iraq and Afghanistan. Neither adversary was able to mount significant resistance to the initial U.S. invasion force, and military commanders predicted a speedy victory in both conflicts.

However, an opponent does not need to be a major power or even a nation-state to find and exploit asymmetries in military conflict. Rather than quick victory, what ensued in the years and decades that followed was a roiling insurgency that found the United States engaged in irregular warfare in both conflicts. While the power disparity between the United States and the former government, tribal, and sectarian groups that resisted occupation was immense, the U.S. military struggled to adapt to this new form of warfare and suppress the insurgencies. A key weapon used by insurgents was the improvised explosive device (IED). As some scholars have noted, "the IED is a near perfect weapon system for balancing this power disparity" (Amoroso & Solis, 2019). The Government Accountability Office (GAO) found that by July 2008, "about 75 percent of casualties in combat operations in Iraq and Afghanistan were attributed to improvised explosive devices" (Sullivan, 2009).

The IED and the ever-present threat of IEDs had many impacts on the conflicts. It restricted freedom of activity for U.S. forces, making it more difficult and riskier to move supplies and personnel around the battlefield. It meant that there were no clear front lines in the conflict and no sanctuary. It undermined the ability of U.S. forces to provide security and basic support services to the population, making the United States look like a weak and unreliable partner. Perhaps most notably, IEDs had a disproportionate cost impact on the United States (Amoroso & Solis, 2019). These relatively inexpensive weapons forced the U.S. military to initiate a rapid acquisition program to field armored vehicles capable of protecting service-members from IEDS and to acquire a variety of other counter-IED technologies. From fiscal year 2006 through 2011, these efforts cost some $58 billion in total and arguably shifted DoD's acquisition attention away from longer term threats and modernization needs (Russell, 2012).

A Framework for Evaluating Asymmetries

The examples presented of asymmetries in nature and in military competition highlight the key factors that should be considered when comparing the relative potential of asymmetries. This section organizes these factors into a framework of five questions that can be used to evaluate asymmetries. The factors these questions explore are: the immutability of an asymmetry's source, how difficult it is to restore symmetry by copying or countering, the level of effects at which an asymmetry is anchored and the spectrum of operations it supports, an asymmetry's ability to leverage other underlying asymmetries, and its ability to scale. The first two questions assess the ability of an asymmetric advantage to endure, the third and fourth questions assess the degree to which it maximizes leverage, and the fifth assesses its potential for exponentiality. Throughout this discussion, Blue refers to the party attempting to use an asymmetry (whether friend or foe) and Red refers to the party an asymmetry is being used against.

1. How immutable is the source of the asymmetry?

Perhaps the most important factor to determining whether an asymmetry is likely to endure is the immutability of its source. The most immutable sources of asymmetry arise directly from the laws that govern the physical universe. At higher levels of complexity in the environment and in the interactions within that environment, the factors that give rise to asymmetries can themselves be more variable and changing, making the asymmetry less likely to endure. The asymmetry of nuclear weapons relative to conventional weapons, for example, arises directly from immutable differences in the fundamental forces of nature that govern nuclear reactions (i.e., the strong nuclear force) and chemical reactions (i.e., the electromagnetic force). Geography is immutable in many ways but not entirely. While major shifts in geography tend to occur over many millennia, rising ocean levels threaten to reshape coastlines and reclaim low-lying islands within decades. Countries blessed with an abundance of fossil fuels may have an advantage today, but those resources can become depleted, and the relevance and utility of these resources can change over time. Technology is an often-touted source of asymmetry, and it played a key role in the Second Offset strategy (Metz & Johnson, 2001, p. 10). But technology is not immutable because it is always advancing and changing, and the rate at which technology advances is increasing as more people and organizations have access to the tools and resources needed to produce new technologies (Roser, 2023).

2. How difficult is it to copy or counter?

The endurance of an asymmetric advantage also depends in large part on how difficult it is for Red to revert the competition to symmetry by coping or countering the asymmetry. In the example of nuclear weapons in the New Look strategy, the Soviet Union recognized the asymmetric advantage the United States held in these weapons and worked to quickly build up its own nuclear forces. Even though the source of the asymmetry was the immutable laws of physics, it ceased to be asymmetric when the Soviets were able to create a comparable capability for themselves. While this undermined the asymmetry, it did not completely undermine the strategy because it led to a stable and roughly symmetric equilibrium between the two superpowers in the nuclear dimension of the competition. Financial, scientific, and political barriers may make an asymmetry difficult for Red to steal or independently develop, as has proven to be the case for most other nations seeking nuclear weapons. Even if Red can copy an asymmetry, it may not be able to generate symmetric effects because of other underlying asymmetries, such as geography. Asymmetries that rely on specific technical knowledge or the idea itself being kept secret to prevent it from being copied will only endure for as long as that secrecy can be maintained—or until Red makes the same discovery independently.

Red can also seek to restore symmetry by developing effective counters to an asymmetry. Counters can include protective measures an adversary takes that seek to limit the effects an asymmetry has, or they can involve active measures that attempt to disrupt or degrade its use. Ideally for Blue, the counter will be exponentially more difficult than the asymmetry itself and require substantial resources that detract an adversary from building other military capabilities, making it more likely that the asymmetric advantage will endure. For example, the direct counter to the nuclear-armed ICBMs in the New Look strategy was a missile defense system that could intercept these missiles in flight—a much more challenging technical problem than the ICBMs themselves. An asymmetric advantage that is critically dependent on other supporting capabilities can also create vulnerabilities an adversary can use to counter the asymmetry. The U.S. military's failure to adequately protect its ISR and command and control systems, particularly in space, created a vulnerability for its precision strike asymmetric advantage that adversaries have sought to exploit (Harrison et al., 2021, pp. 1–2).

As Red works to counter an asymmetry, Blue can also take actions to counter Red's counters. For example, the IEDs used by insurgents in Iraq and Afghanistan led the U.S. military to field more heavily armored vehicles and to develop better technology to detect and disable IEDs before they could detonate. Insurgents countered these counters by developing a variety of fuses and detonators that were more difficult to defeat and using shaped charges to penetrate thicker plates of armor. As one writer has noted, the most effective counter to IEDs proved to be at a higher level of effect than the IED itself—a "change in relationship between U.S. troops and the local population made the greatest difference in overall security conditions, including with the IED" (Shell, 2017).

3. At what level of effect is the asymmetry anchored, and how applicable is it across the spectrum of operations?

The degree of leverage an asymmetry provides depends in part on the level of effects at which it is anchored. The level of effects can be thought of as a continuum that begins at the scientific and technical levels and rises through the tactical, operational, strategic, and national levels. While some have noted that "the most common form of asymmetry resides at the operational level," asymmetries can exist at many other levels as well (Metz & Johnson, 2001, p. 9). The New Look strategy of massive retaliation was anchored at the strategic level, while the asymmetry of IEDs used by insurgents in Iraq and Afghanistan was anchored at the tactical level. The higher the level at which an asymmetry is anchored, the more leverage it can provide.

A related dimension is how applicable an asymmetry is across the spectrum of conflict. The spectrum of conflict can be thought of as an orthogonal dimension to the level of effects that spans from cooperation through competition, crisis, and conflict, as shown in Figure 3. The more broadly applicable an asymmetry is across the spectrum, the more useful it becomes in practice. Asymmetries are particularly advantageous if they can deter a situation from escalating to crisis or conflict. Massive retaliation, for example, proved to be an effective deterrent at the strategic level across competition and crisis because it created a strong incentive for an adversary not to escalate. Precision strike, however, was not an effective deterrent at the operational level in competition and crisis. Even after its effectiveness in conflict was demonstrated in the 1991 Gulf War, the credible threat of U.S. military intervention with its precision strike advantage was not sufficient to compel belligerent forces in Bosnia or Kosovo to back down. If the overarching strategy is aimed at deterrence, Blue's focus should be on finding asymmetries that can be applied left of crisis and at higher levels of effect. Asymmetries that rely on secrecy or surprise for their effective employment, and therefore cannot be revealed in advance of their use, may only be applicable in crisis or conflict and have little (if any) effect in cooperation and competition.

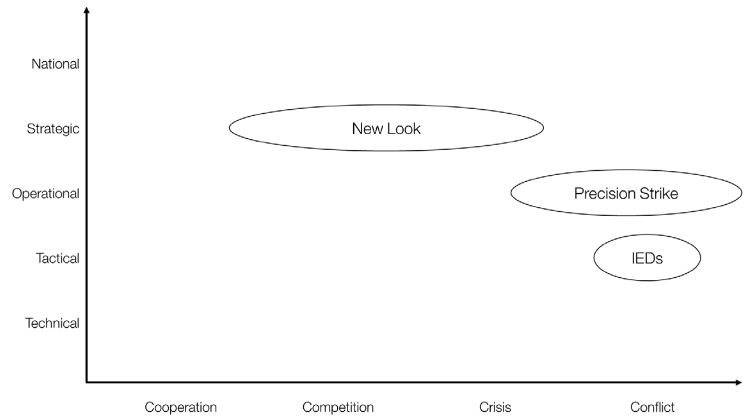

Figure 3. Example Diagram of Level of Effects Versus Spectrum of Operations

4. Does it leverage other underlying asymmetries?

Asymmetries that build synergistically on other asymmetries can greatly enhance the leverage they provide and the complications they create for an adversary. For example, the precision strike asymmetry the United States sought to exploit in the Second Offset leveraged an immutable geographic asymmetry between the United States and the Soviet Union, namely that the Soviets had a much larger and precarious border to defend in the land, sea, and air domains. By some estimates, Soviet spending on air defenses exceeded that of the United States by a factor of ten (Lepingwell, 1989). U.S. advances in stealthy aircraft, such as the F-117A fighter and B-2 bomber, complicated an already difficult air defense challenge for the Soviet military and negated many of the investments they had already made. Layering asymmetries with other asymmetries can create an integrated advantage that is greater than the advantages each provides independent of one another. However, layered asymmetries that are interdependent on one another (meaning they cannot function separately) can introduce vulnerabilities Red may seek to exploit.

5. How well does it scale?

The ability of an asymmetry to scale is a critical factor in how much advantage it can provide. As an asymmetric advantage is exploited in larger numbers or to a higher degree, it may have diminishing or increasing returns on its effectiveness (i.e., non-linear scaling). There may also be thresholds beyond which its effectiveness abruptly changes (i.e., step functions). Nuclear weapons, for example, quickly reach a point of diminishing returns once a nation has enough weapons to deliver a secure and devastating second strike against all adversaries. Having more weapons beyond this point provides less and less incremental advantage. It is also important to understand how costs scale with an asymmetry—both the costs it imposes on Red and the costs of the asymmetry itself for Blue. Ideally for Blue, the costs imposed on Red will increase faster than the costs Blue incurs. It could be a linear relationship between the two (e.g., the costs imposed are X times more than the costs incurred), or it could be a more complex non-linear relationship. There may be a point at which the costs imposed and the costs incurred cross over one another, as in a square-cube law relationship, making an advantage become a disadvantage (or vice versa). These scaling dynamics are also connected to the ability of Red to counter the asymmetry, Blue's counter to Red's counter, Red's counter to Blue's counter of Red's initial counter, and so forth through some number of *n*-counter cycles. An asymmetry that grows stronger (i.e., becomes harder for Red) as *n* increases scales favorably for Blue, whereas one that gets weaker (i.e., becomes easier for Red) as *n* increases does not.

Applying the Framework

In any discussion of historical examples, one enjoys the advantage of hindsight because the outcomes of these examples are already known—another example of the time asymmetry at work. In the case of this analysis, historical examples of asymmetries in military competition serve to highlight the strengths and weaknesses of each asymmetric approach and to construct a framework for comparing asymmetries. However, when it comes to applying this framework forward to evaluate future asymmetries, the time asymmetry is a distinct disadvantage because we know much less about the future than the past. But our understanding of the future, however crude and imprecise it may be, is immensely more valuable to the decisions that must be made today to prepare for whatever future awaits. This section applies the framework developed for evaluating asymmetries to areas that are often touted as potential asymmetric advantages. The aim is to assess the relative potential of these asymmetries and aid our understanding of how military resources can be most effectively applied today. As with any complex assessment, the five factors assessed in the framework do not simply combine into a single metric to determine the best asymmetry overall. Rather, they work together to provide a more comprehensive understanding of the conditions under which one asymmetry may be better than another.

Ubiquitous ISR

The large-scale deployment of increasingly capable remote sensing satellites and highly proliferated terrestrial and airborne surveillance technology is creating an unprecedented level of transparency on Earth with a reach that transcends national borders. Satellites are particularly well-suited for broad area surveillance because of their altitude, freedom of overflight, and the regularity of orbits. A satellite in a sun synchronous orbit, for example, traverses from pole to pole as it orbits the Earth and, depending on its sensor suite, can sense across broad parts of the spectrum, from visible and infrared light to radio frequency signals. As more satellites are added to constellations, the revisit rate (i.e., the time between satellites passing over a given point on Earth) continues to go down and the amount of data collected continues to climb. Of course, the increase in remote sensing capabilities that are making ISR more ubiquitous is not limited to satellites—a variety of airborne and networked terrestrial-based sensors, ranging from drones to traffic cameras, are also increasing the ISR capabilities available. Remote sensing systems can use active sensing, such as synthetic aperture radar that can see through clouds and at night, or passive sensing, such as electro-optical imagery that relies on reflected sunlight or RF sensing that detects, geolocates, and characterizes stray radio emissions. A key enabler of ubiquitous ISR is the software that automates the processing of raw data into intelligence products and combines data from multiple space-based, airborne, and terrestrial sensors to create a near-real time view of the Earth and what is happening on it. This trend in ISR is also extending in the opposite direction, with more sensors pointed away from Earth at objects in space. The unprecedented level of insight into what is happening on and around the Earth has the potential to create an information asymmetry. The asymmetry is not that one side will have more information than the other; rather, the asymmetry is that a nation seeking to conceal activities within or beyond its own borders may no longer be able to do so.

<u>Immutability of the Source:</u>

The underlying sources of ubiquitous ISR are both the physics involved in remote sensing and the software technology that enables automated processing of sensor data into actionable intelligence. The physics of remote sensing is immutable because it is based on the fact that electromagnetic signals (light, radio waves, etc.) naturally radiate outward in free space, making it possible to observe them from a distance. In contrast, the use of AI and ML software to increasingly automate the processing and exploitation of data is not immutable; it is rapidly changing and advancing.

Ability to Copy or Counter:

The capabilities that enable ubiquitous ISR are widely available (including commercial space remote sensing systems), and they are not difficult for a state or non-state actor to access. The benefit derived from copying this capability, however, can be asymmetric depending on who it is being used against (see Synergies below). There are many ways an adversary can counter ISR systems, such as camouflage, concealment, deception, blinding sensors, spoofing sensors, and disrupting the communications systems that support information dissemination. This naturally leads to what is likely a perpetuating hider-finder competition.

Level of Effects and Applicability Across the Spectrum:

Ubiquitous ISR is anchored at the tactical level because its primary effect is to enable a better near-real time understanding of what is happening in the battlespace and broader environment. It is applicable across the full spectrum of operations, from cooperation through conflict—although its use in conflict may be curtailed depending on how resilient the enabling capabilities are to attack.

Synergies with Other Asymmetries:

Ubiquitous ISR can act synergistically with other asymmetries that exist between different societies and forms of government. The advantage for Blue is much greater when used against a Red government that attempts to maintain tight controls on information within and beyond its borders. When used against an open and free society, however, ubiquitous ISR is less likely to reveal information that was not already known. Moreover, the very structure of free and open societies allows them to benefit from greater knowledge of themselves (e.g., more effective and transparent enforcement of laws).

Ability to Scale:

The effects of ubiquitous ISR increase in a linear fashion at first (e.g., doubling the number of sensors doubles the information collected), but at scale it produces diminishing returns because sensors begin to overlap with one another in time, space, or spectrum. The added value from each additional observation diminishes as more of the observations contain redundant information (e.g., multiple pictures of the same car in the same parking lot around the same time).

Hypersonic Weapons

The development of hypersonic weapons has been a priority for the U.S. military for several years. The 2018 NDS specifically cited hypersonic weapons as one of the "technologies that ensure we will be able to fight and win the wars of the future." By definition, hypersonic weapons fly more than five times the speed of sound—much faster than conventional cruise missiles—and they can be more maneuverable than ballistic missiles, making them more difficult to track and intercept. Part of the push to accelerate the development of these weapons is a perceived gap with Russia and China, which are reportedly more advanced in hypersonic weapons. As Michael White, principal director for hypersonics in the Office of the Undersecretary of Defense for Research and Engineering, noted in public comments, this gap in capability "presents a battlefield asymmetry and timescale that we simply cannot allow to stand" (Cronk, 2021). According to the Congressional Research Service, the DoD is investing in multiple hypersonic weapons development programs in parallel at a cost of $4.7 billion in FY 2023 alone, which is up from $3.8 billion in FY 2022 (Sayler, 2023).

Immutability of the Source:

The source of asymmetry in hypersonic weapons is technology—specifically the propulsion, flight control, and thermal management systems that enable controlled flight at these speeds. As previously discussed, technology is a fleeting source of advantage because it is constantly changing and evolving.

Ability to Copy or Counter:

As with any technology, hypersonic capabilities can be replicated by other nations, as the United States is currently attempting to do. However, the resources and technical expertise required can create significant barriers for many other nations. A key asymmetric aspect of hypersonic weapons is the fact that they are more difficult to counter than cruise missiles and ballistic missiles. While ballistic missile defense is commonly compared to hitting a bullet with a bullet, defending against hypersonic weapons is more like trying to hit a highly maneuverable bullet with a bullet.[1] The FY 2024 budget request projects it will take 17 years of development before the DoD can begin fielding a new hypersonic defense system (Missile Defense Agency, 2023, p. 613).

Level of Effects and Applicability Across the Spectrum:

Hypersonic weapons provide a tactical-level capability. While they are designed for use in conflict, they can also be applicable in competition and crisis. The ability of hypersonic weapons to hold targets at risk that other weapons may not be as effective at striking can increase deterrence in competition and potentially deter escalation in conflict if their use is deemed credible.

Synergies with Other Asymmetries:

Hypersonic weapons work synergistically with geography. Because of their range and speed, they provide a greater advantage for Blue when attempting to strike highly defended Red targets from a distance, as compared to cruise missiles and ballistic missiles. A cruise missile takes much longer to reach targets over long distances (hours of flight time versus minutes at hypersonic speeds), and a maneuverable hypersonic missile is harder to defend against than a traditional ballistic missile. For Russia and China, hypersonic weapons provide an ability to target U.S. and allied bases and capital assets (such as aircraft carriers) from the relative sanctuary of their mainland. For the United States, these weapons provide the ability to strike highly defended and time-sensitive targets deep within another nation from standoff range.

Ability to Scale:

With current technology, hypersonic missiles are more expensive than their alternatives, making them more difficult to field at scale. The Congressional Budget Office estimates that “hypersonic missiles would cost roughly one-third more than ballistic missiles with maneuverable warheads that had the same range and accuracy and traveled at similar speeds” (Kramer et al., 2023). Moreover, CBO notes that hypersonic weapons are only needed for a relatively small number of potential targets that are well-defended and time-sensitive, meaning they would add a diminishing incremental advantage when fielded in larger quantities because there would be fewer targets that require them.

[1] For more on the challenges of defending against hypersonic missiles, see Karako and Dahlgren’s (2022) *Complex Air Defense: Countering the Hypersonic Missile Threat*.

Commercial Innovation

The DoD has made a deliberate effort in recent years to improve its ability to leverage commercial innovation. The 2022 National Defense Strategy explicitly states that the DoD "will be a fast-follower where market forces are driving commercialization of military-relevant capabilities," and that the DoD will increase collaboration with the private sector to leverage "its technological advancements and entrepreneurial spirit to enable new capabilities" (DoD, 2022, pp. 19–20). The democratization of technology means that more people and companies in the private sector have access to the design tools and other enabling technologies that make rapid innovation possible. According to Organization for Economic Cooperation and Development data, U.S. government and business R&D spending were roughly equal in 1981, but by 2020 R&D spending by U.S. businesses had grown to be 3.3 times that of the U.S. government.[2] The asymmetry for the United States is not a set of specific commercial technologies with military applications. Rather, the asymmetry is the free market economic system and access to capital that enables commercial companies to produce innovative technology. The U.S. commercial sector is widely considered more vibrant and innovative than that of its competitors, namely Russia and China, and it has a deeply rooted culture of entrepreneurship that encourages risk-taking and innovation (Hill et al., 2023).

Immutability of the Source:

The source of commercial innovation is the economic, social, and cultural systems that enable it. While the economic system of a nation can change, these changes usually occur over many decades, and a nation's social and culture systems change even more gradually. The United States and many of its allies and partners have had (largely) free market economic systems and open societies for many decades, if not centuries, and this is unlikely to change in the foreseeable future.

Ability to Copy or Counter:

The technology and capabilities that result from Blue commercial innovation can be copied by Red, as is evident by the extensive efforts both China and Russia have made to steal U.S. commercial technology (Editorial Board, 2022). Red could also attempt to counter each technology as it emerges. But this puts Red at a perpetual disadvantage—it will always be attempting to catch up to the latest Blue commercial innovations. The most effective long-term counter would be for Red to develop a commercial innovation base of its own that is comparable to Blue's.[3] This may not be a viable option for countries like China, Russia, and other authoritarian regimes because the conditions necessary for a vibrant commercial sector—namely an open society and free market economic system—would erode the foundation upon which their regimes are based. In other words, they would have to become more like the United States to counter the asymmetry commercial innovation provides.

Level of Effects and Applicability Across the Spectrum:

Commercial innovation stems from the fundamental economic and governance system of a nation, anchoring it at the national level. It is most applicable in cooperation and competition, but commercial innovation can play an important role in crisis and conflict by augmenting military capabilities and enabling the ability to scale production of key items. In this situation, the relationship between the

[2] Author's analysis of OECD data: https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

[3] Russia attempted to create a Silicon Valley of its own, known as the Skolkovo Innovation Center, beginning in 2010 under former Russian President Dmitry Medvedev. But after more than a decade of operating under an authoritarian regime and with multiple incidents of corruption, the effort has "failed to produce a single unicorn [or] even a company that has become a household name" (Hlebanov, 2022).

commercial sector and the military is likely to be substantially different than it is in peacetime.[4]

Synergies with Other Asymmetries:

As previously discussed, commercial innovation is more advantageous when it is combined with an asymmetry between Blue and Red's forms of government and types of society (Blue's being free and open and Red's being authoritarian and closed). It also pairs well with a preexisting economic asymmetry where Blue has a much larger economy than Red.

Ability to Scale:

When the government scales its use of commercial innovation, either by using commercial approaches more in existing areas or expanding the use of commercial approaches into new areas, it is leveraging a much larger private investment, creating a multiplier effect for every dollar the DoD spends. Moreover, the effect becomes exponential when considering the speed at which innovation occurs in the commercial sector, where the time between new generations of technology is often measured in months rather than decades and the rate of change is ever increasing.

Final Thoughts

Asymmetries have historically been a powerful source of military advantage, but as this paper has shown, not all asymmetries are created equal. Asymmetries vary significantly in their ability to endure, the degree to which they maximize leverage, and their potential to scale effects exponentially. The framework presented in this paper is intended to serve as a basis by which current and future asymmetries can be evaluated and compared. The three example asymmetries analyzed (ubiquitous ISR, hypersonic weapons, and commercial innovation) serve to demonstrate how the framework can be applied across a variety of areas and are not intended to be a comprehensive listing of potential asymmetries. The goal of the framework is to help decision makers identify asymmetries that have the greatest potential.

The framework also highlights some of the key weaknesses in previous offset strategies—weaknesses that the U.S. military risks repeating in its current attempts to identify a new offset. The First Offset was subject to being copied, which allowed the Soviets to restore a level of symmetry in the competition. The Second Offset, in addition to being readily countered and copied, was based on a mercurial source—technology—that provided only a fleeting advantage. Moreover, the Third Offset strategy called on a laundry list of potential technologies, such as AI and autonomous systems, that are not likely to produce an enduring advantage for similar reasons as the first two offsets.

The 2022 National Defense Strategy rightly specifies that the asymmetric advantages it wants to pursue are those that will endure. This corresponds to asymmetries that are based on relatively more immutable sources and that are relatively more difficult to copy or counter. The strategy also focuses on the concept of integrated deterrence—shifting the competition into areas where the United States can leverage all areas of national power and influence in a coordinated manner. This calls for asymmetries that anchor at the national level of effects, that are applicable in the cooperation and competition phases of operations (i.e., left of crisis), and that leverage other underlying asymmetries beyond just the military aspect of the competition. The ultimate objective is not to fight and win wars—the goal is to win without fighting. Finding and pursuing the right asymmetric advantages is the key to establishing a stable and enduring deterrence posture for the future.

[4] For example, in World War II the U.S. government took unprecedented steps to control the commercial sector by rationing materials and fuel and by turning automotive factories into aircraft factories (Automobile Manufacturers Association, 1950).

Metrea Strategic Insights

Metrea Strategic Insights (MSI) specializes in pathfinding studies that look beyond the typical five-year planning horizon at long-term trends, threats, opportunities, discontinuities, and asymmetries in national security. MSI is led by Managing Director Todd Harrison and is supported by a team of experts with a variety of experience in government, industry, think tanks, and academic institutions. MSI does not take institutional positions, and any views expressed in this publication are solely those of the author(s).

MSI's parent company, Metrea, provides effects-as-a-service to national security partners in four domains and over a dozen mission-centric solution areas, including airborne ISR, aerial refueling, electronic warfare, communications, space-based ISR, and advanced simulation. Metrea leverages commercial business models to unleash innovation cycles that anticipate emerging threats. Metrea is headquartered in Washington, DC with facilities across the United States, the United Kingdom, and the EU.

References

Amoroso, P., & Solis, M. (2019, May28). Improvised explosive devices, a near perfect asymmetric weapon system of necessity rather than a weapon of choice. *Small Wars Journal*. https://smallwarsjournal.com/jrnl/art/improvised-explosive-devices-near-perfect-asymmetric-weapon-system-necessity-rather-weapon

Automobile Manufacturers Association. (1950). *Freedom's arsenal: The story of the automotive council for war production*. The Association.

Biden, J. (2021, February 4). *Remarks by President Biden on America's place in the world.* The White House. https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/02/04/remarks-by-president-biden-on-americas-place-in-the-world/

Bitzinger, R. A. (1989). *Assessing the conventional balance in Europe, 1945–1975.* RAND. https://www.rand.org/content/dam/rand/pubs/notes/2007/N2859.pdf

CIA. (n.d.). *The world factbook.* Retrieved March 23, 2023, from https://www.cia.gov/the-world-factbook/

Close, F. (2000). *Lucifer's legacy: The meaning of asymmetry.* Oxford University Press.

Comptroller General of the United States. (1978). *Report to the Congress: Additional cost of the all-volunteer force.* U.S. Government Accountability Office. https://www.gao.gov/assets/fpcd-78-11.pdf

Cronk, T. M. (2021, May 3). Defense official says hypersonics are vital to modernization strategy, battlefield dominance. *U.S. Department of Defense News*. https://www.defense.gov/News/News-Stories/Article/Article/2593029/defense-official-says-hypersonics-are-vital-to-modernization-strategy-battlefie/

Darwin, C. (1872). *The origin of species.* P F Collier & Son. https://rauterberg.employee.id.tue.nl/lecturenotes/DDM110%20CAS/Darwin-1859%20Origin%20of%20Species.pdf

Diamond, J. (1999). *Guns, germs, and steel: The fates of human societies*. W.W. Norton & Co.

DoD. (2018). *2018 national defense strategy*. https://dod.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf

DoD. (2022). *2022 national defense* strategy of the United States of America. https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF

Eddington, A. S. (1948). *The nature of the physical world.* Cambridge University Press. https://henry.pha.jhu.edu/Eddington.2008.pdf.

Editorial Board. (2022, April 18). America is struggling to counter China's intellectual property theft. *Financial Times*. https://www.ft.com/content/1d13ab71-bffd-4d63-a0bf-9e9bdfc33c39

Eisenhower, D. D. (1952, October 21). *Text of the address by Dwight D. Eisenhower, republican nominee for president, delivered at Detroit, Michigan*. https://www.eisenhowerlibrary.gov/sites/default/files/research/online-documents/korean-war/i-shall-go-to-korea-1952-10-24.pdf

Eisenhower, D. (1956, October 17). *Address at a rally in the civic auditorium.* Seattle, WA. https://www.eisenhowerlibrary.gov/eisenhowers/quotes#War

Farley, R. (2012, November 6). Asymmetry. *Information Dissemination*. http://www.informationdissemination.net/2012/11/asymmetry.html

Gardels, N. (2010, February 5). China is aiming at America's soft underbelly: The internet. *The Christian Science Monitor*. https://www.csmonitor.com/Commentary/Global-Viewpoint/2010/0205/China-is-aiming-at-America-s-soft-underbelly-the-Internet

Gentile, G., Shurkin, M., Evans, A. T., Grisé, M., Hvizda, M., & Jensen, R. (2021). *A history of the third offset, 2014–2018*, 7–40. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA454-1.html.

Goulding, V. J., Jr. (2000). Back to the future with asymmetric warfare. *Parameters, 30*(4). https://press.armywarcollege.edu/cgi/viewcontent.cgi?article=2005&context=parameters

Harris, J. F., & Graham, B. (1999, June 3). Clinton is reassessing sufficiency of air war. *Washington Post*. https://www.washingtonpost.com/archive/politics/1999/06/03/clinton-is-reassessing-sufficiency-of-air-war/eaf709c3-89fa-4664-8dba-8d2e5b018fb2/

Harrison, T., Johnson, K., & Young, M. (2021). *Defense against the dark arts in space: Protecting space systems from counterspace weapons.* Center for Strategic and International Studies. https://csis-website-prod.s3.amazonaws.com/s3fs-public/publication/210225_Harrison_Defense_Space.pdf

Hill, S., Ionescu-Somers, A., Coduras, A., Guerrero, M., Menipaz, E. E., Boutaleb, F., Zbierowski, P., Schøtt, T., Sahasranamam, S., & Shay, J. (2023). 2022/3 global report: Adapting to a "new normal". *Global Entrepreneurship Monitor*. https://www.gemconsortium.org/reports/latest-global-report

Hlebanov, S. (2022, April 22). Skolkovo: The story of Russia's failed attempt to build its own Silicon Valley. *The Business of Business*. https://www.businessofbusiness.com/articles/skolkovo-russias-failed-silicon-valley-tech-putin/

Johnson, K., Harrison, T., Young, M., Wood, N., & Goessler, A. (2022). *Space threat assessment 2022.* Center for Strategic and International Studies. https://aerospace.csis.org/space-threat-assessment-2022/

Jones, M. J., Evans, A. J., Johnson, B. C., Weller, M. B., Andrews-Hana, J. C., Tikoo, S. M., & Keane, J. T. (2022). A south pole–Aitken impact origin of the lunar compositional asymmetry. *Science Advances,* 8(14). https://doi.org/10.1126/sciadv.abm8475

Karako, T., & Dahlgren, M. (2022, February 7). *Complex air defense: Countering the hypersonic missile threat.* Center for Strategic and International Studies. https://www.csis.org/analysis/complex-air-defense-countering-hypersonic-missile-threat

Kimball, D. (2022). U.S.-Russian nuclear arms control agreements at a glance. *Arms Control Association*. https://www.armscontrol.org/factsheets/USRussiaNuclearAgreements

Krajewski, P. (2012, November 15). Symmetric warfare—The return to symmetry. *CIMSEC.* https://cimsec.org/symmetric-warfare-back-to-symmetry/

Kramer, C., Mosher, D., & Keating, E. G. (2023, January). *U.S. hypersonic weapons and alternatives.* Congressional Budget Office. https://www.cbo.gov/publication/58924#:~:text=CBO%20estimates%20that%20hypersonic%20missiles,for%20them%20is%20well%20developed

Kysela, D. T., Brown, P. J. B., Huang, K. C., & Brun, Y. V. (2013). Biological consequences and advantages of asymmetric bacterial growth. *Annual Review of Microbiology,* 67, 417–435. https://doi.org/10.1146/annurev-micro-092412-155622

Lepingwell, J. W. R. (1989). Soviet strategic air defense and the stealth challenge. *International Security, 14*(2), 64–100. https://doi.org/10.2307/2538855

Livio, M. (2012). Why symmetry matters. *Nature*, 490, 472–473. https://doi.org/10.1038/490472a

McGilchrist, I. (2012). *The master and his emissary: The divided brain and the making of the western world.* Yale University Press.

Metz, S., & Johnson II, D. V. (2001). *Asymmetry and U.S. military strategy: Definition, background, and strategic concepts.* U.S. Army War College. https://apps.dtic.mil/sti/pdfs/ADA387381.pdf

Missile Defense Agency (2023, March). Department of Defense fiscal year (FY) 2024 budget estimates. *Defense-Wide Justification Book 2a*. https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2024/budget_justification/pdfs/03_RDT_and_E/RDTE_Vol2_MDA_RDTE_PB24_Justification_Book.pdf

Office of the Undersecretary of Defense for Research and Engineering. (2022). *Technology vision for an era of competition*. Department of Defense. https://www.cto.mil/wp-content/uploads/2022/02/usdre_strategic_vision_critical_tech_areas.pdf

Roser, M. (2023, February 22). Technology over the long run: Zoom out to see how dramatically the world can change within a lifetime. *Our World in Data*. https://ourworldindata.org/technology-long-run

Russell, C. B. (2012, August 1). *Counter-improvised explosive devices: Multiple DoD organizations are developing numerous initiatives.* U.S. Government Accountability Office. https://www.gao.gov/assets/gao-12-861r.pdf

Salam, A. (1990). The role of chirality in the origin of life. *International Centre for Theoretical Physics*. https://inis.iaea.org/collection/NCLCollectionStore/_Public/22/052/22052504.pdf

Sayler, K. M. (2023, February 13). *Hypersonic weapons: Background and issues for Congress.* Congressional Research Services. https://sgp.fas.org/crs/weapons/R45811.pdf

Shell, J. (2017, May 1). How the IED won: Dispelling the myth of tactical success and innovation. *War on the Rocks*. https://warontherocks.com/2017/05/how-the-ied-won-dispelling-the-myth-of-tactical-success-and-innovation/

Skeptic's Play. (2009, February 12). *Darwin's flatfish flounder.* https://skepticsplay.blogspot.com/2009/02/darwins-flatfish-flounder.html

Sullivan, M. J. (2009, October 8). *Testimony before the house armed services committee, defense acquisition reform panel: Rapid acquisition of MRAP vehicles.* U.S. Government Accountability Office. https://www.gao.gov/assets/gao-10-155t.pdf

Ziegler, C. E., & Menon, R. (2014). Neomercantilism and great-power energy competition in Central Asia and the Caspian. *Strategic Studies Quarterly, 8*(2), 17. https://www.jstor.org/stable/26270802

Acquisition Research Program
Department of Defense Management
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net