Part I
Nuclear Deterrence and Arms Control

Chapter 1
Deterrence and Arms Control in an Era of Rapid Technological Change

Daryl G. Press

Nuclear weapons have been in the news recently. Provocative nuclear threats from Russia, delivery system improvements by North Korea, and a major nuclear expansion by China have made deterrence and arms control more politically salient than at any time for decades. But as noteworthy as those events are, the more significant and longer-term changes in the nuclear landscape have attracted less attention. The unprecedented technological changes that are sweeping through all aspects of society, and through every corner of the global economy, are also having powerful effects on nuclear deterrence.

The sources of these changes are familiar: the computer revolution is unleashing waves of improvements in guidance systems, automation, data processing, and remote sensing. No one should be surprised to read that artificial intelligence (AI) is being used to search for mobile nuclear delivery systems, or that autonomous submersibles are hunting for submarines, or that modern guidance systems create pinpoint accuracy.

But what is not widely appreciated, even throughout the nuclear community, is how the cumulative impact of these technological changes is challenging the core assumptions of deterrence strategies, force posture, and arms control. In the new age of counterforce, many of the old assumptions about how to create stable nuclear deterrence need to be reevaluated.

In the first section of this paper, I summarize the core claims of nuclear deterrence theory, and I argue that significant increases in force vulnerability will complicate deterrence and arms control. The next section describes the implications of advanced accuracy for nuclear deterrence, including some non-intuitive implications. The third section summarizes some of the major changes in remote sensing, as they affect nuclear weapons and deterrence. The last section of the paper explores some of the implications of changing technology for deterrence and arms control.

The Logic of Nuclear Deterrence

At its core, deterrence theory claims that nuclear war will be deterred if countries believe that launching a nuclear attack on an enemy will trigger a devastating retaliatory blow in return. That condition will be met as long as nuclear-armed countries possess a sufficiently-survivable force so that they can (a) absorb a disarming strike, and (b) *subsequently* inflict unacceptable damage on those who attacked. Nuclear deterrence therefore rests, at its core, on the concept of survivable retaliatory forces.

To be clear, maintaining survivable retaliatory forces is not the only thing a country must do to deter its enemies: for example, a country must demonstrate the will to retaliate as well as the capability.[1] But maintaining forces that are sufficiently survivable to absorb an attack and subsequently inflict an unacceptable retaliatory strike on the attacker is the foundation of a robust deterrent.

The good news about nuclear weapons is that they are uniquely well-suited for deterrence for three reasons. First, nuclear weapons are small and therefore easy to hide. As a result, finding an enemy's nuclear weapons to destroy them is very difficult. Second, nuclear weapons are highly destructive per unit. The implication is that a country that wishes to disarm a nuclear-armed enemy must find and destroy nearly *all* of the enemy's weapons. Missing even a few of them could be catastrophic. And third, nuclear weapons are easy to deliver: in the missile age, defenses are leaky.[2]

Taken together, these three physical attributes explain why a successful disarming strike against a nuclear rival is very difficult: it is difficult to find his weapons, and yet you must find them all. And any weapons that survive a disarming attack will be deliverable against one's homeland. Love them or hate them, nuclear weapons are the ultimate tool of deterrence.

Experts on nuclear deterrence disagree about many things. For instance, they disagree about *how probable* nuclear retaliation must be to make nuclear deterrence sufficiently robust. Those on the "optimistic" side of the continuum often argue that even a vulnerable nuclear arsenal will have a large deterrent effect, because even a small

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1 Demonstrating that one has the will to retaliate is not always simple, especially if one is trying to use nuclear threats to deter attacks on an ally (i.e., extended deterrence), or to deter other attacks that do not in themselves raise existential risks. The issue of "will" is important and runs throughout the deterrence literature, but it rests on top of the core question of *capability*: can a force survive and retaliate?

2 Keir A. Lieber and Daryl G. Press, *The Myth of the Nuclear Revolution: Power Politics in the Nuclear Age* (Ithaca, NY: Cornell University Press, 2020), 15.

probability of suffering terrible retaliation will deter most rational actors from attacking.[3] Those on the more "pessimistic" side disagree; they point out that nuclear deterrence must succeed even against the most aggressive enemies, and even in dark times, for example during an intense crisis or a war, or even when an enemy is enraged and desperate. These scholars argue that for deterrence to be truly reliable, in even the most extreme circumstances, retaliation should be "assured."[4]

Similarly, optimists and pessimists disagree about how much destruction must be threatened in order to convince all potential attackers that the consequences are too horrendous to face. Optimists say that merely threatening a couple of enemy cities is plenty to deter; pessimists say that a threatened retaliatory strike must be far greater to ensure that deterrence holds in any conceivable situation.[5]

Where most nuclear experts agree, however, is that changes that make nuclear forces significantly more vulnerable to destruction are worrisome. Those changes are worrisome for two distinct reasons. First, they may tempt countries during crises or wars to attempt disarming strikes. Second, the *fear* that an enemy may launch a disarming strike will cause (a) arms races, (b) alerted nuclear postures, (c) mutual distrust, and (d) the conditions for escalation during periods of heightened tension (due to the heightened mistrust and the opportunity to weaken the enemy's nuclear arsenal).

Concerns about the consequences of nuclear force vulnerability are particularly important today because the world is undergoing a set of technological changes that are greatly reducing the survivability of nuclear forces. These technological changes are not being adopted evenly by all countries; the U.S. is a leader in many of them. But many of

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3 The view that vulnerable nuclear arsenals will adequately deter is widely held among many deterrence theorists, including McGeorge Bundy, Kenneth Waltz, and Richard Ned Lebow. The view is nicely captured by Avery Goldstein, who writes, "Nuclear-armed states do not need to convince a potential aggressor that retaliation is certain, or even likely, only that it is possible…." Avery Goldstein, *Deterrence and Security in the 21st Century: China, Britain, France, and the Enduring Legacy of the Nuclear Revolution* (Stanford, CA: Stanford University Press, 2000), 44-46.

4 Although many academic deterrence theorists subscribe to the "optimistic" view, nuclear armed countries have nearly-universally rejected that view for their own forces. The United States and the Soviet Union (now Russia) have always based their deterrent posture on the concept of assured destruction. Additionally, the United Kingdom, France, India, Pakistan, Israel, and North Korea seem to agree. For years the exception was China, which fielded a vulnerable arsenal and explained that, in its view, "assured retaliation" was unnecessary. Interestingly, that situation has changed; as China became more powerful and geopolitically active, it began to create a true "assured destruction" posture.

5 See the discussion of the logic behind four competing views – existential deterrence, minimum deterrence, assured retaliation, and assured destruction – in Lieber and Press, *The Myth of the Nuclear Revolution*, 33-41.

the key technologies are diffusing around the globe. Taken together, these changes have critical implications for deterrence and arms control.

Changing Technology and Nuclear Weapons

In this section, I describe the major technological changes underway by focusing on two areas: improvements in accuracy and remote sensing.

The Age of Pinpoint Accuracy

The accuracy revolution has transformed conventional warfare *gradually*. The first "precision guided munitions" were employed more than 50 years ago by the United States during the Vietnam War, but it was not until the 21st century that guided weapons became the "normal" munition for U.S. air and naval forces. In other words, it took five decades from the first TV-guided missiles hitting a bridge in Vietnam until the moment we have reached today, in which virtually every munition fired by the U.S. Air Force or Navy is guided by digital links, laser designators, or GNSS systems.[6] And even today, most U.S. land-warfare munitions remain unguided.

The application of precision guidance to the nuclear domain has been even slower. In the United States, nuclear delivery systems generally do not depend on signals from external sources.[7] There are at least three reasons for this restriction. First, external navigation systems – like GPS and the other GNSS constellations – may not be available in a nuclear environment.[8] Second, signals – for example from data links or GNSS – may be vulnerable to manipulation. And lastly, making a nuclear weapon capable of receiving signals opens an "attack surface" on the weapon that enemies could use to corrupt the delivery system itself. As one expert in the nuclear enterprise commented, "I wish our enemies would allow their nuclear weapons to receive midcourse navigation updates; we'd be in there in a minute."[9]

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[6] GNSS stands for global navigation satellite system, such as GPS, Galileo, BeiDou, GLONASS, Michibiki, GINS, and others.

[7] An exception is that U.S. ballistic missiles use stellar navigation to update their position after boost phase.

[8] Key navigation systems may be intentionally targeted during a nuclear conflict, and therefore nuclear delivery systems are not permitted to depend upon them. In fact, nuclear detonations may disrupt the electromagnetic environment and degrade guidance systems even if the navigation infrastructure is not directly attacked.

[9] This is nearly an exact quote (I was not taking notes during the conversation).

Despite the (wise) reluctance to allow nuclear delivery systems to depend on guidance information from external sources, the accuracy revolution is coming to nuclear weapons. Improvements in gyroscopes, accelerometers, magnetometers, digital scene matching, and other techniques have greatly increased the accuracy of nuclear-armed ballistic missiles, cruise missiles, and bombs. In the mid-1980s, the most advanced U.S. ballistic missile had an accuracy of 183 meters. By 2010, the average "miss distance" for U.S. ballistic missiles was down to 90-120 meters.[10] And recent upgrades have reduced those distances again to approximately 60 meters.[11] U.S. nuclear bombs (as opposed to ballistic missiles) are even more accurate, with the upgraded B61-12 reportedly having "near GPS" accuracy (perhaps 30 meters) without relying on GPS.

But what is the impact of these accuracy improvements on deterrence? The revolution in accuracy is greatly increasing the ability of countries to conduct disarming strikes against enemy nuclear forces, weakening the foundation of deterrence.

Improved accuracy has at least five major effects on nuclear deterrence:

1. <u>Pinpoint accuracy increases the effectiveness of strikes against hardened targets</u>. In 1985, a 2-on-1 strike using warheads from a U.S. Minuteman III against a Russian missile silo had roughly a 79% chance of success. Against the same target today, two warheads would have (approximately) a 96% chance of success.[12]
2. <u>Pinpoint accuracy allows countries to employ multiple weapons against a single target</u>. Until recently, countries could employ at most two ballistic missile warheads against each target because of fratricide concerns. The accuracy revolution has greatly reduced fratricide risks, allowing for 3-on-1 (or more)

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[10] These figures reflect the "circular error probable" (CEP) of the missiles, which is the median miss distance. By definition, half the weapons fired at a target will fall within 1 CEP of that target, and half will fall further away. A smaller CEP means a more-accurate missile. For data on U.S. missile accuracy, see Keir A. Lieber and Daryl G. Press, "The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence," *International Security*, Vol. 41, No. 4, Appendix Table A1 and footnote 3.

[11] The United States upgraded its Trident II and Minuteman III ballistic missiles with variable height of burst fuzes, which improve those missiles' effectiveness against hardened targets to a degree that is roughly equal to a 40% improvement of accuracy. On the fuzes, see Hans M. Kristensen, Matthew McKinzie, and Theodore A. Postol, "How US nuclear force modernization is undermining strategic stability: The burst-height compensating super-fuze," *Bulletin of Atomic Scientists*, March 1, 2017. See also, Lieber and Press, "New Era of Counterforce," pp. 23-24 and Appendix pp. 3-6.

[12] These calculations assume a silo hardness of 3,000 psi and a warhead yield of 335 kilotons. The 1985 missile is a Minuteman III with 183 meters CEP; the current version of the missile has an upgraded guidance package and approximately 120 meters CEP. The 96% figure *does not account for the benefits of variable height of burst fuzes*. For the calculations and underlying data, see Lieber and Press, "The New Era of Counterforce," pp. 19-21 and Appendix pp. 1-2.

targeting. This change has received little attention, but it has had a huge effect on force vulnerability, making complete disarming strikes against large target sets possible for the first time since the 1950s.[13]

3. Pinpoint accuracy allows attackers to destroy hard targets with small-yield nuclear weapons. Until recently, striking hardened targets required high-yield nuclear weapons. As accuracy improves, countries can destroy very hard targets with low-yield weapons, allowing attackers to significantly reduce collateral damage.[14]
4. Pinpoint accuracy allows attackers to destroy hard targets with airbursts. Throughout the Cold War, destroying hard targets required ground burst detonations, which create substantial nuclear fallout. Very high accuracy allows countries to destroy hard targets with airbursts, which would create little or no fallout, greatly reducing the civilian consequences of nuclear strikes.[15]
5. Pinpoint accuracy allows attackers to destroy hard targets with conventional weapons. As accuracy continues to improve, nuclear targets will increasingly be vulnerable to attacks with conventional (non-nuclear) weapons, reducing civilian casualties even further and possibly lowering inhibitions to disarming strikes. The implications of conventional counterforce for arms control are substantial and described below.

In sum, nuclear delivery systems are now far more accurate, and the implication for force survivability is significant. Hard targets can now be destroyed reliably by using multiple strikes, comprising of low-yield weapons, and in some cases they can be set to detonate as airbursts. In the near future, it will be possible to conduct counterforce strikes

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13 For an excellent explanation of nuclear fratricide, see Bruce W. Bennett, "How to Assess the Survivability of U.S. ICBMs" (RAND Corporation, 1980). For an explanation of why the accuracy revolution greatly reduces the fratricide problem, see Lieber and Press, "The New Era of Counterforce," pp. 21-22 and Appendix p. 3.

14 The destructive radius of a nuclear detonation depends on the warhead's yield *raised to the one-third power*. As a result, if accuracy improves by 50% (for example, from 180 meters CEP to 90 meters), targetters could have the same effectiveness against a hardened target using a warhead with 1/8th the yield as before the accuracy upgrade. Note that the accuracy of U.S. ballistic missiles has improved by approximately 50% twice since 1985. As a result, warheads with approximately *1/64th of the yield* would have the same effectiveness against hardened targets as their Cold War predecessors. This helps explain why the United States is now deploying very low yield warheads on its ballistic missile submarines. For the formulas to derive these calculations, see Lieber and Press, "The New Era of Counterforce," Appendix p. 1, which relies upon Lynn E. Davis and Warner R. Schilling, "All You Ever Wanted to Know about MIRV and ICBM Calculations but Were Not Cleared to Ask," *Journal of Conflict Resolution*, Vol. 17, No. 2 (June 1973): 207-42.

15 See Lieber and Press, "New Era of Counterforce," pp. 27-32 and Appendix pp. 6-7.

with mostly conventional weapons. Strategies of deterrence and arms control need to account for the new age of accuracy.

Revolutions in Remote Sensing

While advances in accuracy are making hardened nuclear targets more vulnerable, leaps in remote sensing are undermining the survivability of concealed and mobile forces. In the ongoing game of "hide and seek" waged by mobile missile commanders and submariners against the forces seeking to track them, the job of the "hiders" is growing more difficult.

At least five mutually reinforcing trends are ushering in an age of unprecedented transparency.

1. New sensor platforms. Sensor platforms have become more diverse. The foundations of Cold War remote sensing – satellites, manned aircraft, submarines, and undersea hydrophones – are still crucial, but now they are aided by new platforms, among them unmanned aerial vehicles (UAVs), unmanned undersea vehicles (UUVs), unattended ground sensors, cyber spying, and more.
2. New types of intelligence. Cold War strategic intelligence relied heavily on photoreconnaissance, underwater acoustics, SIGINT, and ELINT, which all remain central to strategic reconnaissance operations. Now, however, sensors gather much broader ranges of data. Sensors have moved from relying mostly on the visible parts of the electromagnetic spectrum and infrared to exploiting the entire electromagnetic spectrum. Additionally, platforms now use spectroscopy to identify the vapors leaking from facilities; other satellites employ interferometry to discover underground facilities, and synthetic aperture radar (SAR) to track moving targets. And unattended ground sensors use seismic, acoustic, and radiological sensors to identify vehicles and in some cases their cargo near critical sites.
3. Sensors and the platforms that carry them perform better than they did in the past. Sensor resolution is steadily improving. Increasingly, U.S. sensors are carried on platforms that can provide persistent surveillance of critical adversary sites (e.g., through long-endurance UAVs circling outside enemy airspace, or through UUVs operating near or inside enemy waters). Persistent observation provides streams of data rather than snapshots, which is essential for characterizing enemy operational patterns in peacetime, and for tracking their forces during crises or wars.
4. Leaps in computer processing power. Perhaps most importantly, dramatic

increases in computer processing power are allowing better analysis of the large quantities of remote sensing data that is being gathered on nuclear forces. AI is helping to sort raw intelligence data and identify concealed and moving targets among the background noise. Sceptics caution that early AI algorithms were vulnerable to spoofing. But the *essence* of AI and machine learning is detecting subtle patterns amidst a sea of noise. As AI algorithms improve, and are trained using more and more data (e.g., of submarine or mobile missile signatures), and as processor speed continues to increase, the challenges for those whose job it is to hide submarines and missile launchers will continue to increase.[16]

5. The future of sensing? Lastly, countries are just now starting to explore the first generation of "quantum sensors," which hold the promise of greater sensing capabilities than is possible using traditional techniques. Some of the applications of quantum sensing are in the undersea domain. There is debate among experts about how difficult it will be to build robust, reliable quantum sensors, but even those on the skeptical side of that debate estimate that the deployment of relatively mature quantum sensing systems will occur in roughly a decade. Ongoing research in quantum computing will likely accelerate the development, deployment, and capabilities of quantum sensors.

Finally, missile defenses, which do not fit neatly into the "accuracy and sensing" framework, are witnessing major breakthroughs that, combined with accuracy and sensing, are stressing the "survivable retaliation" logic of deterrence.[17] Vast improvements in the sensitivity of missile defense radars (e.g., the new SPY-6) do not merely allow defense systems to track and engage smaller and more distant targets; they greatly increase the "footprint" of defense systems, meaning the area that a system can protect.

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16 There is a debate about whether AI can be employed equally effectively for spoofing. See for example Edward Geist, *Deterrence Under Uncertainty* (Oxford, 2023), chapter 5. Even skeptics of AI, however, concede that the operators of nuclear forces will have less confidence in the survivability of their own nuclear systems.

17 One missile defense breakthrough that has already occurred is the use of gallium nitride semiconductors in U.S. sea-based missile defenses (e.g., the SPY-6 and the EASR) to increase the radar sensitivity by *35 times*. One result of the increased sensitivity is the great expansion of the "footprint" that a missile defense system can protect, allowing a small number of sea-based platforms to protect continent-sized areas (like the United States). This breakthrough, in conjunction with possible progress in decoy differentiation (by observing frequency variations among objects of different mass) will not create impenetrable defenses, but they are undermining the retaliatory capability of nuclear forces (e.g., after absorbing a disarming strike). I thank Jaganath Sankaran for bringing this to my attention. See Kris Osborn, "Nothing Will Be Able to Hide from the Navy's New Spy-6 Radar," *The National Interest* (July 12, 2022).

Additionally, guided by longer-range radars, missile defenses are expanding their ability to conduct "shoot-look-shoot" engagements, which are key to improving the effectiveness of defenses against medium-sized (or bigger) attacks.

In short, missile defenses complement the capabilities described above. Accurate missiles (described above) are straining the ability of small- and medium-sized arsenals to survive disarming strikes. Advanced sensors are putting mobile nuclear systems at risk. And improved missile defenses are, for the first time, creating real possibilities that defenses can "mop up" those few weapons that survive an attack. Building a survivable nuclear deterrent in this environment is not impossible, but it takes more care than it did a few decades ago.

It is likely that none of these technological trends alone will be transformative. But taken together, they are creating a combination of accuracy, sensing, and defenses that were unimaginable even two decades ago. The accuracy revolution is already here; the sensing revolution is unfolding. Combine them with improvements in missile defense and we have a world in which the old assumptions about deterrence and arms control need to be carefully scrutinized.

Implications: Deterrence and Arms Control in the 21st Century

Even with these technological changes, it is possible to build force structures and deterrence postures that will create a robust deterrent, and to do so without dangerous policies like "launch on warning" or major force expansions that would trigger an arms race. But doing so will require care and a willingness to reconsider old approaches. I offer five tentative suggestions and observations about arms control and deterrence below.

1. Smaller is not always better. For decades, the arms control community was wedded to the idea that reducing the size of nuclear arsenals reduced the likelihood of nuclear war. There was good reason to hold that belief during the Cold War, when the superpowers had tens of thousands of weapons at high degrees of readiness. But arsenals around the world are much smaller today. In an era of pinpoint accuracy, revolutionary sensors, and improvements in missile defenses, reducing arsenal sizes may actually increase countries' vulnerability to disarming strikes, and hence elevate nuclear dangers, especially during conventional wars and nuclear crises.
2. Symmetry may not be safe. For decades, symmetry was an important tool that arms controllers used to create safe, stabilizing arms control agreements – but the

accuracy revolution makes symmetry a less effective tool in the future.

In the past, symmetrical nuclear reductions allowed countries to reduce arsenals while maintaining survivable retaliatory forces. Symmetrical arms cuts enhanced security because during the Cold War, only nuclear weapons could destroy hardened nuclear sites. As a result, reducing forces eliminated sites that would need to be destroyed in a disarming attack (which weakens deterrence), but also eliminated the weapons that were necessary to carry out an attack (which strengthens deterrence). In fact, because several weapons are typically required to destroy each hardened site, cutting forces symmetrically could make arsenals less vulnerable to attacks. Hence, arms control reduced the incentives for disarming strikes through symmetrical reductions.

The problem is that as conventional weapons become better for disarming strikes, agreements that leave two adversaries with small, symmetrical arsenals may leave them both vulnerable to disarming strikes – with conventional weapons leading the way. Symmetry is no longer a guarantee of survivability.[18] Stated differently, arms cuts now reduce the number of targets that must be destroyed but do not limit the weapons that can conduct those strikes (because many of them are conventional). A critical tool in the arms control tool kit is therefore now much weaker.

3. Do not fall in love with submarines. Throughout most of the Cold War, knowledgeable academics, think tank experts, and former government officials frequently asserted that the superpowers' submarine forces were essentially invulnerable, and therefore both superpowers possessed a secure retaliatory capability. We now know this was incorrect. In fact, there were periods of the Cold War in which the United States was tracking and trailing all Soviet submarines.[19] Equally importantly, the Soviet Union often did not know the state of the naval balance at any given time. Submarines have a "fail-deadly" quality: a set of technological and operational breakthroughs may transform the most survivable leg of a country's nuclear arsenal into the most vulnerable leg – without any signs that such a transformation has occurred.

Are submarines survivable today? If the Cold War is a guide, the answer likely

18 This problem is even worse in an age of nuclear tripolarity.

19 See, for example, Austin Long and Brendan Rittenhouse Green, "Stalking the Secure Second Strike: Intelligence, Counterforce, and Nuclear Strategy," *Journal of Strategic Studies*, Vol. 38, Nos. 1-2: 38-73. See also the various first-person accounts of U.S. anti-submarine warfare efforts during the Cold War.

depends on the specific submarine force, the training and skill of their crews, and the state of the back-and-forth technological arms race in undersea sensing.

Will submarines remain survivable in the future? Again, the answer undoubtedly depends on the countries involved: those doing the hiding, and those doing the hunting. But what seems clear is that in an era of unprecedented technological change, and in a time in which the leading military powers are investing great sums in sub-surface operations and sensing, basing one's nuclear deterrent on the assumption that large tubes of metal will forever remain invisible seems like an unwise gamble.

The answer, of course, is not to eliminate submarines but to build a balanced force structure in which submarines and other forces combine to create a difficult target set. Submarines are a key part of a secure nuclear deterrent, but not a solution by themselves.

4. Evaluate *systems* of sensors – not individual technologies. Well-meaning arms control advocates seem motivated to demonstrate that each new technology (developed, in many cases, precisely for the purpose of hunting mobile targets) cannot possibly work. They often reach this finding by highlighting limitations to first-generation technologies, and by modeling new sensors' capabilities *independently* rather than as part of a sensing / hunting system.

The Cold War provides useful information about how the United States hunts challenging, mobile targets. In both anti-submarine and anti-mobile missile operations, the U.S. approach had several key ingredients.

- Peacetime observation to learn adversary operating patterns, patrol areas, preferred routes, timing and means of communication, key waypoints, and more;
- Creation of systems of sensors, focused at strategic locations, to detect and if possible track adversary forces;
- Practice tracking and (if applicable) following deployed adversary forces.

The United States conducted operations like this against the Soviet submarine force for decades, and is probably doing similar things today in multiple regions. Hunting land-based mobile missiles requires different platforms and sensors, but the overall pattern is the same: peacetime surveillance using multiple platforms and sensors, monitoring chokepoints and waypoints, and using the adversary's own deterrent patrols (and alert behavior) to practice tracking.

The point is that the state of the balance – at any given moment – cannot be precisely measured from outside the walls of a *few offices* inside the Pentagon (even the Russians and Chinese are probably not certain how survivable their deterrent forces are). But the direction of the balance seems clear: the revolution in sensing (and vast improvements in guidance systems and missile defenses) is giving much better tools to the hunters.

5. How to deter in the 21st century? How should a country approach deterrence in an era of unprecedented technological change? The answer is not new, but hopefully it is clarifying: An era of rapidly changing technology calls for a force structure that (1) includes diverse delivery systems, and (2) includes elements that are mobile and elements that present hardened targets.

Diversity of delivery systems has always been valued in a nuclear force structure because it helps insure against unforeseen technological change. That consideration has never been more important than it is now. Additionally, a diverse nuclear posture means that potential attackers must solve several distinct problems: conducting highly-accurate strikes against the hardened targets, and also tracking and destroying mobile systems. Diverse target sets also create timing problems for an attacker: a successful attack on enemy mobile delivery systems may require time to unfold, giving warning that a broader attack is underway. And finally, having diverse forces can provide a sense of safety to those who field them, so they do not need to interpret ambiguous signs or warnings of attack in the most pessimistic way.

There is one other attribute of a force that may be controversial – and is in tension with other things in this paper: it is valuable to have elements in a force that can be visibly alerted in ways that create additional force survivability. For the United States, having the ability to disperse its bomber force during a crisis permits Washington to signal (either quietly or openly) that it is concerned about the direction of a conflict – and thus taking steps to ensure the survivability of its arsenal. To be sure, alerting forces can be escalatory, but communication is valuable, especially during a crisis.

What does a force with these attributes look like? For a country like the United States, which spends significant sums on national security, a modestly-sized diverse nuclear arsenal looks like the triad that the United States fields today, and which the United States is poised to modernize. Calls to eliminate the U.S. ICBM force are unwise, as they would rest the peacetime survivability of the U.S. arsenal entirely on the future of the submarine / ASW competition. One could improve on the current U.S. triad by adding land-based mobile missiles to supplement the silo-based ICBM force (or replace some of the silos), but the political hurdles to that seem high.

For other countries, such as those with advanced technology but a limited defense budget, a pretty good, pretty survivable, and diverse nuclear arsenal could be built on either two or three legs, such as: (1) attack submarines with nuclear-armed cruise missiles, (2) air-delivered weapons stored in vaults under hardened aircraft shelters, and (3) mobile land-based missiles (which would have the advantage of adding ballistic missiles to the force, which would otherwise be only cruise missiles and bombs). To make a force like this more survivable, a country could build additional shelters and storage vaults to allow aircraft to disperse or move among a large number of hardened aircraft shelters to complicate enemy targeting.

In short, a survivable deterrent is feasible, but it is not simple and requires careful analysis and attention.

Trends in technology are complicating deterrence, and they raise real challenges for future arms control agreements. But deterrence is not hopeless – it simply requires greater care. The first step is to move beyond the slogans and assumptions from a different era, when arsenals were enormous, accuracy was poor, and sensors were primitive. None of those things is true anymore, so our policies and strategies must adapt.

The second step is committing ourselves to practice nuclear deterrence responsibly. Basing one's own security on the threat to use nuclear weapons is strategically and ethically defensible, but only if the strategy is executed with great care and seriousness. Simply assuming that nuclear arsenals will remain invulnerable, despite the lessons of history and the directions of technology, would be nuclear malpractice. A robust deterrent must be survivable, and survivability in an era of unprecedented technological change will require sufficient numbers, diversity, and care.