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Knocking Nuclear Weapons Off Their Pedestal: Emerging Technologies and the Future of Proliferation

For decades now, nuclear weapons have been almost universally regarded as a category apart from all other weapons. Despite fears of widespread nuclear proliferation in the early days of the Cold War, the world knows just nine nuclear possessors in 2020. As the 21st century continues, however, new technologies that may transform the nature of nuclear deterrence and stability are emerging. While many of these technologies interact with nuclear weapons in the realms of delivery systems (for example, hypersonic boost-glide vehicles) and command and control (for example, artificial intelligence), none are likely to knock nuclear weapons off their pedestal. In the coming decades, however, these technologies may contribute to disincentives to nuclear proliferation, primarily by increasing the challenge for new nuclear aspirants in ensuring that their burgeoning nuclear forces will be survivable and, therefore, useful. To date, assuring survivability for nuclear forces has been mostly feasible, even for resource-poor nuclear possessors, but this might not be the case indefinitely – especially if revolutionary technical advances can be made in certain defensive technologies. This essay examines the pathways by which radical technical advances – even those that do not seem technically feasible, given current capabilities – might disincentivize future nuclear proliferation.

NUCLEAR WEAPONS ON THE PEDESTAL

Contrary to some accounts, the detonation of the Trinity "gadget" on July 16, 1945 did not immediately raise nuclear weapons above other forms of ordnance in the views of military planners – even as the Manhattan Project scientists who witnessed that initial detonation firsthand appreciated the devastating power of the plutonium implosion fission bomb. Though the initial use nuclear weapons against Imperial Japan in August 1945 conveyed that an important threshold had been crossed, military planners in the United States before the creation of the civilian-led Atomic Energy Commission treated early US nuclear weapons as an especially large iteration of conventional ordnance (Tannenwald 2005). It was only after the experience of multiple crises, Soviet nuclear breakout ending the US nuclear monopoly, and the "nuclear learning" of the early years of the Cold War between the two superpowers that many of the axioms concerning nuclear deterrence became established and better understood by practitioners. The nuclear taboo – a norm against the use of nuclear weapons – took hold more broadly by the end of the Cold War (Tannenwald 2007). Nuclear weapons have not been employed in conflict since 1945; the most recent case of a country testing a nuclear device for the first time was North Korea in 2006. Cold War-era nascent proliferators, some of whom ended their programs after the Nuclear Nonproliferation Treaty took effect in 1970, learned these lessons themselves, seeing nuclear weapons as a necessary component of their national defense policies until they were forced, primarily for political and diplomatic reasons, to abandon their pursuit of the bomb (Kramer and Brannan 2004). Countries that succeeded in their efforts to acquire nuclear weapons – South Africa (before it disarmed), India, Pakistan, and North Korea – were undeterred from their course by the technical challenge. Other attempts – for instance, by South Korea and Taiwan during the Cold War – were ultimately thwarted by political interventions rather than the technical challenge.

Nuclear weapons had found themselves on a pedestal and appeared to proliferate quickly in the earlier years of the nuclear era. In technical terms, nuclear weapons radically revised earlier understandings of the relationship between the weight of ordnance and explosive yield: an impossibly impractical amount of conventional explosives would be necessary to achieve an effect comparable to that of even the earliest single-stage nuclear weapons, whose explosive yield was in the thousands of tons of TNT equivalent. By the late 1950s, when the first intercontinental ballistic missile (ICBM) was deployed in the Soviet Union, it became apparent that any state on earth that had the appropriate ballistic missiles could in theory threaten another state with unacceptable levels of damage in a matter of minutes. Nuclear competition quickly spilled outside of the Cold War superpower dyad between the United States and Soviet Union as the United Kingdom (1952), France (1960), and China (1964) successfully developed nuclear weapons. As of 2020, nuclear weapons remain a special class of weaponry, with just nine known state possessors and a robust set of institutional, normative, and technical barriers to their proliferation in place.

A key question for the coming decades is whether any technical developments can displace the fundamental marriage between delivery vehicle and payload that made nuclear forces a central component of the national defense strategies of the powers that developed them and a few smaller states that turned out to be determined proliferators.

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CAN A DEFENDER'S ADVANTAGE BE REALIZED?

Traditionally, possessors of nuclear offensive arms have been able to find acceptable levels of survivability – the ability of a sufficiently large part of one's nuclear forces to survive a nuclear or conventional attack – at moderate cost, even if political leaders have feared the effect of defensive systems. When an attacker's and defender's nuclear forces are sufficiently survivable, both are more likely to appreciate a condition of mutual vulnerability, which is stabilizing, depriving both of the incentive to use nuclear weapons against the other. While elegant in theory, this idealized notion of perfect strategic stability has not obtained in observed nuclear competitions. Despite the commonly repeated notion that the United States and the Soviet Union accepted some sort of stabilizing condition of "mutual assured destruction," the reality was that each side faced persistent insecurities throughout the Cold War as a result of concerns about the other side's qualitative and quantitative offensive advantages. Instead of accepting some level of strategic mutual vulnerability – which would have been stabilizing – both sides charted courses to develop defensive systems and planned counterforce targeting strategies to limit damage in case strategic deterrence were to fail. In the post-Cold War era, these instincts have persisted – especially in the United States, where advances in everything from sensor arrays to conventional precision strike systems to nuclear-force readiness have made avoiding vulnerability and challenging the survivability of the adversary's nuclear forces appear more feasible (Lieber and Press 2006; Lieber and Press 2017).

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North Korea's test of the Taepodong-1 technology demonstrator in 1998 spurred Washington and its allies to take strategic missile defense more seriously (Namatame 2012). This in turn led to the genesis of the Ground-Based Midcourse Defense (GMD) program by the Clinton administration's National Missile Defense program, which the George W. Bush administration then used as a pretext to exit the 1972 Anti-Ballistic Missile Treaty in 2002. US lawmakers supported the effort by approving the National Missile Defense Act of 1999. China and Russia, meanwhile, have responded to massive US investments in missile defense by focusing primarily on devising measures to defeat enemy missile defenses rather than developing their own missile defenses – partly out of a recognition that assuring the survivability of one's own forces is more feasible than threatening the survivability of the opposing forces. When Russian President Vladimir Putin, in a 2018 speech to the Russian Federal Assembly, described a panoply of exotic new delivery systems that the country's defense establishment was exploring, he justified the effort in part by citing the US pursuit of missile defenses in the aftermath of the Bush administration's exit from the ABM Treaty (Putin 2018). Similarly, China's investments in multiple independently targetable reentry vehicles and hypersonic boost-glide vehicles such as the DF-17 are driven by similar concerns.

In the years since its inception, US testing of the GMD system has yielded a lackluster record, with all publicly available evidence suggesting that the system has fallen well short of its design objectives (Grego, Lewis, and Wright 2016). US policymakers often refer to missile defense as a "shield," but GMD – the only strategic defensive system that is currently in operation and has been demonstrated to be capable of intercepting ICBM-class targets – has fallen well short of meriting that description (Korda 2019). Nevertheless, Russia and China continue to take US investments in missile defense seriously – largely on the assumption that qualitative breakthroughs may yet be possible in ways that could revolutionize the offensive advantage that long-range nuclear-tipped ballistic missiles have long enjoyed. The divergence between actual capabilities and feared potential future capability was aptly demonstrated by China's reaction to the deployment of a US AN/TPY-2 X-band radar alongside a Terminal High Altitude Area Defense (THAAD) system in South Korea, with Beijing fearing the effects of this radar on the ability of the United States to cue up Alaska-based ground-based interceptors (GBIs) for defense of the US homeland with earlier warning than would otherwise have been feasible (Ministry of Foreign Affairs of the People's Republic of China 2016).[1]

Future proliferators will likely make similar calculations with imperfect information about the performance of real missile defense systems. Even if a prospective proliferator has ample fissile material at hand, political and strategic incentives to develop nuclear weapons, and a willingness to face great international opprobrium and economic sanctions, development of nuclear weapons might not be worthwhile unless the country were reasonably confident that its new arsenal would be able to hold its adversaries at risk. The story of North Korean acquisition of a usable nuclear arsenal – from the criticality of the Yongbyon 5-megawatt (electric) gas-graphite reactor in 1986 to the first flight test of an ICBM in 2017 – might not be easily repeatable. North Korea's 2017 ICBM tests demonstrated credibly to many observers that the US homeland could be held at risk by North Korea's nuclear weapons. In a future where the GMD system – or a successor – might exhibit a perfect or near-perfect test record, a proliferator like North Korea would find the effort of developing nuclear weapons and the means of delivery to be far too onerous.

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For instance, if the US ability to intercept all ICBM reentry vehicles in their midcourse phase had been demonstrated with a high degree of reliability, North Korea's offensive capabilities would need to grow quantitatively to the point where its ICBMs could greatly outnumber available interceptors – a costly proposition. Or, Pyongyang would need to consider investing in qualitatively different means of nuclear delivery, such as low-flying hypersonic boost-glide weapons that are impervious to interception in midcourse. A would-be nuclear-armed state with limited resources might find that assuring survivability would become a vanishing prospect, not least because its adversaries might possess dominant defensive systems and long-range precision conventional-strike weapons that could carry out preemptive strikes. Even as the prospect of nuclear explosive yields would remain alluring for such a state, the low probability of assuring delivery and the resulting inability to establish the credibility that underpins nuclear deterrence might serve to disincentivize proliferation in the first place. To be sure, no qualitative revolution in missile defense technologies is anticipated in the near future – only gradual refinement. As a result, the offense is likely to retain its traditional advantage – even as defenders remain reluctant to accept mutual vulnerability in the pursuit of absolute security. Even so, the record of how China, Russia, and North Korea interpret the challenge that US missile defense systems pose, notwithstanding the poor track record of these systems to date, suggests that states will continue to reason from worst-case assumptions – that is, they will assume the best of their adversaries' defensive systems.

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1. Chinese experts have described fears of the X-band TPY-2 radar potentially assisting American exoatmospheric kill vehicles in discriminating warheads from physical countermeasures in midcourse as well. In 2016, China rejected US invitations to technical briefings on the THAAD system.

DEFENSIVE CAPABILITIES IN SPACE AND PROLIFERATION

Space-based strategic defenses may also contribute to deterring new proliferators — particularly those seeking to hold at risk the territory of the United States and other resource-rich states. As of today, only the United States has expressed serious interest in developing space-based strategic defensive capabilities, but other countries, including Russia and China, could reasonably follow in the coming decades if technological breakthroughs increase the feasibility of deploying such systems. In addition to strategic missile defense systems, one area that could see greater investment is space-based defensive systems, where new sensors and interceptors may contribute to a greater capability to intercept ballistic missile reentry vehicles in flight. Like the strategic effects of more-capable missile defenses, these types of capabilities would be destabilizing by reducing the mutual vulnerability that underpins strategic stability. For newer proliferators, such capabilities may present further challenges to assuring the survivability of nuclear forces.

> ***A particular concern for both new proliferators and existing nuclear possessors will be the possibility of advances in undersea, surface-level, and space-based sensors, combined with AI-enabled persistent intelligence, surveillance, and reconnaissance, to target nuclear ballistic missile submarines (SSBNs), which historically have been the most survivable platform for nuclear weapons.***

For resource- and knowledge-poor states, counterspace capabilities might not be a feasible undertaking. Direct-ascent, kinetic-kill anti-satellite weapons — exoatmospheric missiles that head straight from the earth's surface to an overhead satellite target — remain a relatively niche capability in 2020, with known systems existing in China, India, and Russia. (The United States used an SM-3 missile defense interceptor against a decaying satellite in 2008, demonstrating an anti-satellite capability.) Co-orbital counterspace systems, meanwhile, remain relatively rare. If a new proliferator's ballistic missiles would be vulnerable to unreachable, persistent space-based defenses, the benefits of acquiring nuclear weapons in the first place would be greatly blunted. As with the possibility of new advances in missile defense technologies, the challenge of assuring survivability would be insurmountable without serious resource investments in counterspace capabilities or advanced penetration aids.

EMERGING TECHNOLOGIES AND ASSURING SURVIVABILITY

Even without any dramatic advances in missile defense technologies, new nuclear-armed states might be deterred in their pursuit of new capabilities by the incorporation of artificial intelligence (AI) systems into counterproliferation intelligence, surveillance, and reconnaissance activities. Some of these technologies are already being used today, allowing, for example, human intelligence analysts to more quickly analyze vast quantities of raw information, including imagery. Greater advances in this area could make the detection of clandestine nuclear activity more viable (Gartin 2019). As the Central Intelligence Agency's chief learning officer has observed, "The explosion of data has increased the complexity of an analyst's job, but likewise potentially increased the fidelity of many assessments" (Gartin 2019, 3). "We are awash in ones and zeroes that can be linked, analyzed, and leveraged, if we ask the right questions of the right data sets," he adds. The gaps in intelligence and the resulting policy uncertainty that persisted in prior cases, including North Korea, Libya, and Iraq, might be reduced by allowing resource-rich states such as the United States the means to improve its monitoring of potential proliferators.

A particular concern for both new proliferators and existing nuclear possessors will be the possibility of advances in undersea, surface-level, and space-based sensors, combined with AI-enabled persistent intelligence, surveillance, and reconnaissance, to target nuclear ballistic missile submarines (SSBNs), which historically have been the most survivable platform for nuclear weapons. Submarine-hunting is not a new enterprise, and the Cold War featured extensive efforts by the United States and the Soviet Union to simultaneously increase the stealthiness of its own submarines while increasing the ability of its own sensors to track the other's SSBNs. Although the often-referenced dramatic notion of a "transparent ocean" remains far from being realized today, it may not be so indefinitely (Cote 2019). As with the possibility of ballistic missile defenses improving in revolutionary ways, something akin to a transparent ocean may be imaginable in the future. The first-order effects of this would be severe for the major nuclear powers that have relied on continuous at-sea deterrence, such as the United States, the United Kingdom, and France, but this would also deprive new proliferators of a reason to consider sea-based nuclear weapons as a means to increase survivability. This would be true even in the case that strategic ballistic missile defense remained of limited capability as they are today.

Advances in undersea acoustic sensor technology and unmanned underwater vehicles, including autonomous vehicles, could contribute to such a future. Similarly, if more and more sensors were available to collect data, advanced artificial intelligence could assist in the identification of signatures that may be associated with SSBN movements. For instance, a modern iteration of the Cold War-era "deep sound channel" concept, in which underwater acoustic anomalies were detected by US Sound Surveillance Systems (SOSUS), could be imagined with a more sophisticated array of sensors where data analysis could be assisted by artificial intelligence (Long and Green 2015). SOSUS alone was insufficient during the Cold War to come close to identifying the precise location of Soviet submarines, but a new version may be more successful. A future analog to SOSUS may be assisted by autonomous underwater and aerial vehicles and might locate enemy submarines. In doing so, it would upend not only strategic stability between nuclear superpowers relying on SSBNs as the most survivable leg of their forces, but proliferation incentives for states that might have been tempted to pursue the bomb with an eventual plan for sea-based deployment. The survivability of SSBNs, however, remains great, and there are considerable reasons to remain skeptical of the notion of a truly transparent ocean ever materializing to the extent that sea-based nuclear forces would have their traditional survivability advantages fully blunted (Naughton and Brixey-Williams 2016).

OFFENSIVE CYBER TECHNOLOGIES: RISKS AND OPTIONS

Advances in offensive cyber technologies — both those existing today and those yet to come — may significantly complicate the task of countries seeking to acquire nuclear weapons. For instance, nation-states have exhibited some degree of success in interfering in the industrial processes that would be necessary for the production of fissile material and ballistic missile airframes by adversaries. The Stuxnet worm was effective at significantly hindering and damaging Iran's nuclear program at the Natanz Enrichment Complex amid concerns about weaponization activity, for instance (Farwell and Rohozinski 2011). Separately, South Korean sources have reported that North Korea's leadership ordered an investigation into the repeated failures of one of its intermediate-range ballistic missiles, the Musudan, in 2016 (Yonhap News Agency 2016). Public reporting on US efforts to use offensive cyber means to interfere with the missile production supply chains of countries such as North Korea in recent years suggests that the United States sees opportunities for disruption in this area (Panda 2018).

If these capabilities become more robust and vulnerabilities persist in the industrial processes used by potential proliferators, it may be fairly trivial for more-sophisticated countries to sabotage the production of delivery vehicles, for example. This would effectively increase the costs of proliferation; states seeking to develop long-range missiles as delivery vehicles for nuclear weapons would have to improve their cybersecurity or the reliability of their personnel. Where institutionalized export control arrangements might fail to deter a determined proliferator, these types of real costs might come to play a more important role in how states think about the costs of setting up their nuclear forces.

Elsewhere, offensive cyber capabilities will continue to weigh on policymakers as an opportunity and threat. Following the clarification in the 2018 US Nuclear Posture Review that the United States would not rule out the use of nuclear weapons in response to "significant, non-nuclear strategic attacks," many analysts have argued that cyberattacks do not meet this threshold (Office of the Secretary of Defense 2018; Mount and Stowe-Thurston 2018). The NPR is silent on the matter of cyberattacks specifically, but the nongovernmental expert community has interpreted concerns about cyber offensive capabilities to be implicit in this clarification of prior US declaratory policy.[2] The notion that the United States — or other nuclear possessors — would cross the nuclear threshold in response to a cyberattack remains incredible. Cyberattacks have the potential to cause economic losses and damage to infrastructure, but with few exceptions, such as attacks on healthcare facilities that may cause loss of life to patients in critical care, these types of capabilities cannot replicate the damaging effects of nuclear weapons. Strategically, cyberattacks will continue to have great appeal for states at all levels of resources and technical sophistication for their plausible deniability and subsequent high-reward, low-risk nature. But, as noted above, they do not serve the same purposes as nuclear weapons. Because the damage they inflict is not of the same scale, the threatened use of cyber weapons does not have the same deterrent effect as a threat to use nuclear weapons. Similarly, it is not plausible to threaten to use nuclear weapons to respond to a cyberattack.

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The one exception to the above assessment might be cyberattacks that intentionally target the nuclear command, control, and communications apparatus of a nuclear possessor, but such attacks are unlikely to be carried out by states that do not have nuclear weapons. In the cases in which an aggressor with no nuclear arsenal or a very limited one might see strategic value in such an attack (such as Iran or North Korea against the United States), the strategic value of the attack would be moderate. This type of attack would be plausible only if the potential aggressor feared a "bolt-out-of-the-blue" nuclear attack early in a crisis and therefore sought to prevent that possibility by disrupting its enemy's ability to launch such an attack.

WHAT IF DEFENSIVE TECHNOLOGIES REMAIN CONCENTRATED?

Many of the futures imagined in this essay rely on the development of advanced technologies. An embedded assumption, however, is that the country that would likely first develop or master these technologies, from artificial intelligence to ballistic missile defense to undersea acoustics to offensive cyber capabilities, would be a resource-rich superpower. Given this, the first-order effects of many of these developments would be deeply destabilizing. But this destabilizing effect might not be universal; it probably would not apply to states that are considering developing nuclear weapons because of a regional rivalry. For instance, historically, the decisions by India

2. A leaked draft of the 2018 Nuclear Posture Review included language saying that "the President will have an expanding range of limited and graduated options to credibly deter Russian nuclear and non-nuclear strategic attacks, which could now include attacks against U.S. [Nuclear Command, Control, and Communications], in space and cyber space." This language — or a variant — did not find its way into the final document, but the leaked version may offer insights into policymaker considerations in the process of drafting the document. The original leaked predecisional NPR is available at: **https://fas.org/nuke/guide/usa/npr2018-draft.pdf#page=33**.

and Pakistan to pursue nuclear weapons when they did had little to do with the existence of sophisticated anti-ballistic-missile systems and radars in the Soviet Union and the United States.

Future proliferators may, however, have their fates entangled with the superpowers, who may choose to take an interest in their potential pursuit of the bomb for political or diplomatic reasons. For instance, Iran's interest in the bomb through 2003, the date through which the International Atomic Energy Agency had determined Tehran pursued "the development of a nuclear explosive device," had everything to do with Israel's possession of nuclear weapons and the pursuit of a deterrence – but Tehran still found itself in a highly contentious standoff with the United States, Israel's superpower patron, as a result (Quevenco 2015). In the United States, meanwhile, Iran, a country that possessed neither a nuclear weapon nor an ICBM, had been described by the Missile Defense Agency as one of the motivators behind the GMD program, which was officially and nominally designed to defend the US homeland against "limited" ballistic missile threats from Tehran and Pyongyang.

As a result, given the stakes of new 21st century proliferation, even if the futures described here materialize only for technologically sophisticated, resource-rich countries, they will have global effects. There are no "small" proliferators in the end. One way in which certain technologies might be more democratized to rich and poor countries alike is by way of the private sector. Already, high-quality, frequently updated commercial satellite imagery is available to private consumers worldwide. Nation-states with limited indigenous capabilities for satellite imagery could never have imagined having access to these sorts of resources during the Cold War, for instance, when the cutting edge in space-based imagery was limited to a handful of states. Similarly, as countries such as North Korea have demonstrated, sophisticated cyber capabilities need not be the sole preserve of large, wealthy states (Kong, Lim, and Kim 2019). But even while these technologies might be accessible to potential new proliferators, they are unlikely to have a significant effect on the thinking of countries as they decide whether to develop nuclear weapons.

New technologies might deter new proliferators, but could potential proliferators find nonnuclear weapons to be a worthwhile defense investment instead of nuclear weapons? This appears unlikely. The logic that elevated nuclear weapons onto a pedestal during the Cold War relied on the ability of these weapons to impose indiscriminate and high costs on adversaries – with delivery being feasible over long ranges (Wohlstetter 1958). Emerging technologies may have the effect of making nonnuclear precision strikes more feasible on a global scale and making defense against nuclear attack more of a reality, despite decades of overpromised and underdelivered progress on missile defenses. If any contemporary states were to decide to pursue the bomb, it would be because their national leaders perceived nuclear weapons to be providing capabilities that other weapons could not provide.

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CONCLUSIONS

As in recent decades, the main disincentives for nuclear proliferation will come from political, institutional, and normative sources. While several critical technologies will continue to advance, future proliferators generally will not be motivated by technical developments alone. On top of the already robust normative and political disincentives against nuclear proliferation, new proliferators will likely face tremendous difficulty in breaking out in total secrecy and, even if they succeed in building nuclear weapons, will find the pursuit of a survivable nuclear force more challenging than their 20th-century predecessors. This will be doubly true for resource-poor proliferators seeking to deter superpowers, especially as the latter may have increasing access to sophisticated defensive technologies and even offensive cyber means to create complications for the former in the industrial supply chain for ballistic missile production and manufacturing.

It is possible, however, that despite projections that imagine significant leaps in capabilities for missile defense systems, space-based sensors, and other technologies, technical developments in these fields will be incremental because of resource constraints — even in rich countries — or a lack of ability to innovate to overcome the core limitations that have kept these technologies from fulfilling their promise. In such an eventuality, these technologies will remain mostly irrelevant for the prospective proliferator's decision to pursue the bomb in the first place. Like North Korea, which saw fit to master a physics package and flight-test an ICBM capable of holding the United States at risk before worrying about qualitatively and quantitatively pursuing a more survivable nuclear force, states that decide nuclear weaponry is necessary may find that that immediate deterrent effects of these weapons are reason enough to pursue them. The primary inhibitors to proliferation, as a result, will continue to be the institutional and normative mechanisms of restraint that have largely prevailed over the last half century. ■

BIOGRAPHY

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