Originally published in "The Next Fifty Years of Nuclear Proliferation," an Occasional Paper of the Institute for International Science & Technology Policy, IISTP-WP-2021-20, edited by Sharon Squassoni, February 2021.

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Missile Defense and Nuclear Weapons: Charting a Course to Security

In his February 2019 remarks at the Pentagon to unveil his administration's "Missile Defense Review" (MDR), President Donald Trump outlined an expansive vision for missile defense: "Our goal is simple: to ensure that we can detect and destroy any missile launched against the United States – anywhere, anytime, anyplace" (Trump 2019). This caused some confusion and consternation domestically, as it contradicted the MDR itself and long-standing US policy that missile defense was intended to defend the US homeland from the threat of long-range missiles from Iran or North Korea but not from the larger and more sophisticated missile arsenals of major nuclear powers Russia and China. The latter goal has been recognized as technically unachievable, and the effort to attain it would be extremely expensive and strategically destabilizing. The statement also provided fodder for long-held suspicions in Russia and China that US missile defense systems were really intended for them.

While not official policy, Trump's statement echoes a belief that, at least in the United States, has never quite gone away – that missile defenses could be an escape from the horror of vulnerability to nuclear weapons. This belief has persisted, despite decades of work and hundreds of billions of dollars spent in unsuccessful pursuit of such defenses. In one version of this belief, missile defenses would, as envisioned by President Ronald Reagan, make nuclear weapons "impotent and obsolete"

(Reagan 1983). But that is not the universal view. Pursuit of highly effective missile defenses may also reflect the desire of states to escape their own nuclear vulnerability without necessarily giving up the ability to threaten others or doing the hard work to eliminate the weapons entirely. A central argument of this essay, however, is that pursuit of missile defenses for unilateral benefits is likely to confound efforts to chart a path to a stable future free of nuclear threats.

States have been trying to master missile defenses as long as they have been building missiles. It took years of offensive and defensive nuclear competition for the United States and Soviet Union to arrive at a shared understanding of just how interrelated offense and defense were. Eventually the two countries recognized that unconstrained pursuit of missile defenses was both encouraging the arms race, with adversaries building more missiles in order to overwhelm defenses, and creating an incentive to strike first if a crisis seemed imminent because missile defenses might negate an adversary's ability to retaliate. Once this interrelationship became clear, the subsequently negotiated Anti-Ballistic Missile (ABM) Treaty, which limited the United States and Russia to defense of a small geographical area and curbed research and development activities, became the cornerstone of the arms control framework. The nuclear reduction agreements that followed the ABM treaty allowed these nuclear powers to trim their total inventory from a high of more than 60,000 weapons in 1986 to fewer than 10,000 three decades later (Kristensen and Norris, n.d.).

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If the future is to truly be free of nuclear weapons, states should consider carefully how missile defenses might shape incentives to acquire, stockpile, or threaten to use nuclear weapons. Equally important is to evaluate with clear eyes the value that missile defenses can bring.

To do so, this essay will examine the role missile defense has historically played, what its current technical capabilities are and what they might realistically be in the future, and how current plans are shaping strategic choices.

WHY MISSILE DEFENSES?

Missile defenses range from relatively simple battlefield systems designed to defend against short-range rockets and artillery shells to complex global systems to counter nuclear-armed long-range missiles. However, the systems most likely to substantially affect nuclear futures are those designed to defend entire countries from intercontinental-range missiles, systems referred to here as strategic missile defenses. (The line between strategic and nonstrategic missile defense systems is not always clear. Regional systems, designed to defend a smaller geographical area from shorter-range missiles, may, in the right geographic location and supported properly by sensors, have the ability to target long-range missiles over a relatively large area, and so may have strategic capability. Even so, the problem is relatively well bounded.)

Strategic missile defense is an enormously complex and technically challenging task. Intercontinental-range ballistic missiles can be launched with little to no notice, spend three to five minutes in active launch and then coast through space for 30 to 40 minutes at hypersonic speeds before arriving at their target, thousands of miles away. The coasting, midcourse phase provides a longer (but still challenging) timeline for the defense to destroy the incoming missile, but affords the offense the opportunity to use numerous countermeasures to make defense difficult or impossible. For example, the offensive missile may be accompanied through the emptiness of space by lightweight lookalike decoys, forcing the defense to exhaust its resources against harmless objects. Or the offense could detonate some of its nuclear weapons in space or near the atmosphere to interfere with the defense's sensors and thus its ability to target subsequent incoming missiles.[1]

Avoiding these show-stopping obstacles by instead targeting missiles during their active launch, the "boost phase," comes with its own significant challenges. Chief among them is the very short time frame. The missile launch must be detected and defeated within a few minutes, requiring the defense to be geographically close to the launching missile and highly effective, as there will not likely be an opportunity for multiple attempts.

Early on, during the massive nuclear arms buildup in the 1960s, it became clear from a technical perspective that the effective defense of an entire nation against large, sophisticated arsenals would not be achievable. (Nor would it be clearly desirable from a stability perspective.) The major powers turned to more-modest goals for the defense. The Soviet Union built and Russia still fields nuclear-armed interceptors designed to defend Moscow.[2] The United States developed but abandoned almost immediately nuclear-armed systems designed to defend some intercontinental ballistic missile (ICBM) silos and subsequently refocused in the late 1960s to defending the United States from the nascent Chinese ICBM arsenal.[3]

When President Reagan's vision for the Strategic Defense Initiative in the 1980s revisited the idea of a shield-like defense of the United States from the massive Soviet arsenal, the unworkability immediately became clear. In the 1990s, the United States returned to defending against small numbers of relatively unsophisticated missiles from nonpeer potential adversaries — this time Iraq, Iran, and North Korea. This has been the explicit goal for US strategic defense in the last two decades.

EXISTING AND PROPOSED DEFENSES

Currently, the sole fielded system for defending the United States from potential North Korean or Iranian ICBMs is the Ground-based Midcourse Defense (GMD) system, with a core of 44 interceptors based in Alaska and California. This system began development in the 1990s; it was hastened into the field starting in 2002, when the Bush administration withdrew from the ABM Treaty. Its "hit-to-kill" interceptor uses a powerful missile to launch a file-cabinet-sized kill vehicle toward a projected intercept point. The kill vehicle is meant to maneuver itself into a collision with the incoming warhead (or decoy) to destroy it with the force of impact. The system has been plagued by failure, and nearly 20 years after it was initially fielded, has yet to demonstrate a real-world defensive capability against even this limited threat.[4] The system is slated to be expanded to include an additional 20 or more interceptors. This expansion is likely to take at least a decade because the interceptors are undergoing a full redesign and there are no spares available.

To shore up the system in the meantime, the United States is considering repurposing some of its regional and theater-based missile defense systems to assist in defending US territory. This includes the Aegis Ballistic Missile Defense (BMD) ship- and shore-based regional missile defense system, currently in use in by NATO in Europe and by the United States and Japan in East Asia. In the new conception, the Aegis system's new and more capable interceptor, the SM-3 IIA, would be launched from ground-based facilities in the United States or from ships patrolling the country's coasts.

However, while using the Aegis BMD system to support the struggling GMD system might seem a rational step, this is almost certain to substan-

1. Such countermeasures have been well known for decades (Bethe and Garwin 1968). Subsequent reviews of existing systems indicate that little progress has been made in addressing these problems (National Research Council 2012).
2. While public information is relatively scarce, analysts indicate that the Soviet-era system designed to defend Moscow and the surrounding areas from a limited missile attack, the A-135 system,is still in place and still relies on nuclear-tipped interceptors (Kristensen and Korda 2020).
3. In his 1967 speech on "Anti-China Missile Defense and US Nuclear Strategy," Defense Secretary Robert McNamara explained the pivot away from the impossible task of defending against Soviet missiles and toward defending against China. He predicted that China would have a modest ICBM force in the next decade and might be prone to "irrational behavior."
4. The GMD system has undergone 19 intercept tests in 20 years; it failed to destroy its target in nine of them. Three of the eight tests of the currently fielded types of interceptors have failed. (UD GAO 2020, 60). The test conditions have not yet reflected real world conditions, including countermeasures of the type an adversary is likely to use.

tially affect the US-Russia-China strategic balance. The Aegis BMD system, if successfully integrated, would dramatically increase the US strategic missile defense capability, as current plans call for the production of hundreds of SM-3 IIA interceptors deployed on scores of Aegis BMD-equipped ships. However, the GMD and Aegis systems have not demonstrated the technical capability to overcome long-known countermeasures, and their effectiveness will be limited.

Despite the fundamental limitations of midcourse defenses; the public nature of missile defense tests, which have indicated a slow rate of progress; and US reassurances that its strategic missile defense systems are designed for "rogue nation" threats, the sheer size of the US defensive capability is a significant concern for near-peer missile states. A core concern, for Beijing particularly, is that the US system looks oversized and requires too much money for a defense against a rudimentary North Korean threat (Zhao 2020a). Similarly, Russia voices skepticism about the European Phased Adaptive Approach regional missile defense system fielded by NATO to counter Iranian missiles, arguing that it may be out of proportion to the actual threat posed by Iranian nuclear and missile programs. Because any future land-based ICBMs headed toward the United States from North Korea or Iran would travel through northern, near-polar latitudes on paths similar to the ones that Chinese or Russian land-based missiles would use, midcourse defenses designed for North Korea or Iran will have few characteristics that could distinguish them from those that could defend against Chinese or Russian missiles.

While the United States has not pursued space-based missile defense in earnest for decades, the effort never has been completely set aside.

Chinese analyst Wu Riqiang sums up the suspicion about US missile defenses in this way: "[T]he U.S. development of missile defense probably seeks to achieve two goals: it would first use North Korea as the excuse to quietly develop missile defense technologies and integrate different systems; after the technologies become mature it would then enlarge the scope of deployment to neutralize the Chinese and even the Russian nuclear retaliation capabilities" (Zhao 2020a, 33).

Theoretically, a missile defense system could be designed to defend against North Korean missiles but have essentially no capability against China or Russia, such as interceptors hosted on drones loitering outside of North Korean airspace or ships off the North Korean coast that would target North Korean missiles during their boost phase. These systems have attracted little to no interest from the Pentagon, at least in part because it has not been clear they could be built with existing technology.[5]

While the United States has not pursued space-based missile defense in earnest for decades, the effort never has been completely set aside. It is a perennial topic in Congress. Space-based boost phase missile defenses are bound to be extremely expensive; the National Research Council, the operating arm of the National Academies in Washington, estimated that an "austere capability" to defend against one or a few North Korean missiles would require at least 600 satellites and cost $300 billion (National Research Council 2012). With technological advances in materials and miniaturization of components and a decrease in launch costs as commercial competitors enter the market, these systems will become less expensive. But the numbers are never on the defense's side because for at least one interceptor to be within striking distance of the launching missile, many interceptors must be in orbit, as satellites in low-altitude orbits move rapidly with respect to the earth's surface. Additionally, these systems can be evaded or overwhelmed relatively cheaply or simply.

5. Two landmark reports, one from the American Physical Society in 2004 and one from the National Research Council in 2012, found that boost phase defenses against the expected North Korean threat were impractical or unachievable (Barton et al. 2004; National Research Council 2012). Other open-source analysis has suggested it may be possible in certain circumstances (Garwin and Postol 2017).

Despite this, space-based missile defenses have consistently been a central concern for both China and Russia. This may be because by their nature, they are global defenses, less able to be tailored to launches from a particular geographical area than most other missile defense systems. Another problem is that space-based missile defense systems could be used as potent anti-satellite weapons, not only against nearby low-altitude satellites but also those valuable satellites at longer distances (Grego 2011).

Amplifying concerns about missile defense systems are advances in intelligence and surveillance to support targeting of silo-based and mobile ICBMs and in conventional precision strike systems that could target an adversary's command-and-control systems (Glaser and Fetter 2016). Such technologies could support a strategy of effectively striking first and using a moderately effective missile defense to defend against whatever missiles are left, thus escaping mutual vulnerability.

China and Russia have invested many fewer resources than the United States in strategically capable missile defenses. China has been developing and testing hit-to-kill interceptors that could be used against either satellites or ballistic missiles, but it has not fielded the sensors required to support them as a strategic missile defense. This may indicate that its current goal is instead to defend small regions, to simply understand the technology well enough to design its missiles to evade US defenses, or to use the technology primarily as an anti-satellite weapon.[6] Russia has reportedly been modernizing its A-135 Moscow missile defense. It has several systems for air defense and area ballistic missile defense, including the S-500 ballistic missile defense system, which is expected to be deployed in 2020 (US DIA 2017), and a new hit-to-kill interceptor system that may serve as missile defense or an anti-satellite weapon (or both). None of them, however, appears to have the range or sensor support to be strategic defenses.[7]

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MISSILE DEFENSE AND ARMS CONTROL

Whether or not these proposed and fielded strategic missile defense systems are even close to reaching the goals set out for them, the possibility that they might one day realize their potential has led to missile defense playing a considerable role in nuclear postures and having an impact on the prospects for limiting nuclear weapons and delivery systems.

In the early decades of the Cold War, the Soviet Union and the United States each pursued ballistic missile defense as a means to counter the other's increasing inventory of ICBMs. It eventually became clear that any attempt to evade or mitigate vulnerability to nuclear weapons by defending against them was futile, as the adversary could simply build more missiles or design them to carry more warheads. Indeed, the pursuit of such defenses would almost certainly ensure the adversary would do just that, and so limits on missile defenses would be necessary to achieve limits on offensive missiles. The culmination of this logic, the landmark 1972 ABM Treaty, permitted the negotiation of nuclear arms control treaties in the following decades, starting with the 1972 Strategic Arms Limitation Talks Interim Agreement (SALT I) – the first legal constraints placed on US and Soviet offensive and defensive strategic weapons – and continued through SALT II in the 1970s

6. Open-source analysts discuss the tests of the Dong Neng-3 hit-to-kill midcourse interceptor (Weeden and Samson 2020), but China's missile defense systems get little mention in public US intelligence reports, such as the Pentagon's annual report to Congress (US DoD 2019).
7. As with China's missile defense programs, little information is available in government intelligence assessments about Russian missile defense systems that are in development. Some information is available in open-source analysis, such as Weeden and Samson 2020.

and the Strategic Arms Reduction Treaty (START I) and START II in the 1990s.

The US withdrawal from the ABM Treaty in 2002 destroyed this foundation. The day after the US withdrawal, Moscow announced it would no longer be bound by its START II commitments (Arms Control Association 2019), as one of the conditions for Russian ratification of START II was that the United States ratify the negotiated 1997 agreements on ABM Treaty succession, demarcation, and confidence building.[8] While the next nuclear arms reduction treaty, the Strategic Offensive Reductions Treaty (SORT), lowered the permissible number of deployed weapons, important START II provisions, including the prohibition of multiple independently targetable reentry vehicles (MIRVs) on ICBMs, were lost.

The United States and Russia were able to negotiate one more nuclear arms reduction treaty, the New Strategic Arms Reduction Treaty (New START), in 2010. In the treaty's preamble, the two states acknowledged that while the current missile defense systems "do not undermine the viability and effectiveness of the strategic offensive arms of the Parties," "the interrelationship between strategic offensive arms and strategic defensive arms… will become more important as strategic nuclear arms are reduced." As analyst Greg Thielmann notes, the United States and Russia did not necessarily mean the same thing when they referred to the increased importance of the interrelationship (Thielmann 2020). The position of both the Obama and the Trump administrations is that missile defenses are stabilizing, as they reduce the viability of an adversary's first strike. Russia's view is that missile defenses become more destabilizing if the two sides have small numbers of offensive missiles, as they reduce the certainty of second-strike retaliation. Russia has repeatedly stated that including missile defense in discussions is a prerequisite for the next round of nuclear reductions, while US policy is that it will not accept legal limits on missile defenses.

The Chinese nuclear arsenal is about one-seventh the size of the US or Russian arsenal, and despite invitations (and threats) by the United States,[9] Chinese officials have stated very clearly that they are not interested in joining the United States and Russia in a nuclear arms reduction treaty at this time. Indeed, if the menu includes only nuclear reductions, this is likely to hold true for quite some time. However, security concerns among the United States, Russia, and China are broader than simply creating or retaining parity in nuclear arms. US missile defense systems are a core concern for Beijing[10] (as are conventional precision strike weapons and space weapons) and a commitment to discussing them may be the key to bringing China into strategic discussions and arms control negotiations.

MISSILE DEFENSE AND NUCLEAR POSTURES

Without the treaty limitations that once bounded this problem, missile defenses play an important role in nuclear states' decisions about the size and composition of their nuclear arsenals. Russia, China, and the United States are all modernizing their nuclear arsenals: Russia is in the midst of a modernization program that includes replacing its Soviet-era missiles with newer ones; China has been increasing the quality and quantity of its nuclear forces; and the United States is embarking on its own revamping of its triad of nuclear delivery systems.

Currently, Russia and the United States are each limited by New START to 1,550 warheads on 800 deployed and nondeployed strategic launchers. Currently, Russia fields approximately 812 warheads on 302 land-based ICBMs and 560

8. The successor agreement would have formalized the status of the former Soviet republics of Belarus, Kazakhstan, Russia, and Ukraine as parties to the treaty. The demarcation agreement would have clarified the difference between theater and strategic missile defense systems. The confidence-building agreements would have required an exchange of information between the parties to the treaty about theater missile defense systems covered by the demarcation agreement and notification before testing them.
9. Marshall Billingslea, the US special presidential envoy for arms control, stated that the United States "know[s] how to spend the adversary into oblivion" in an arms race (Hudson Institute 2020).
10. Analyst Tong Zhao states that "missile defense generates more Chinese suspicion about the U.S. military's strategic intentions toward China than anything else" (Zhao 2020b).

warheads on its nuclear-armed submarines (Kristensen and Korda 2020). In the absence of New START constraints, Russia and the United States could rapidly upload more warheads onto their existing ICBM forces.

Despite this enforced parity, it appears that Russia assesses US missile defense capabilities as a challenge to its ability to credibly threaten nuclear retaliation. Moscow has been explicit about this concern in official policy statements, including its recent listing of "military risks" that must be "neutralized by implementation of nuclear deterrence" (Putin 2020). The document calls out in particular the development of space-based missile defense. Russia appears to object not just to strategic defenses, but also to regional defenses located on its periphery, as evidenced by Russian threats to use nuclear weapons against NATO missile defense installations.[11] This may be less connected to any capability of these systems to target Russian strategic missiles (which the NATO system does not have) than to the intrinsic ability of the launch tubes in the system to launch cruise missiles and intermediate-range missiles as well as missile defense interceptors.

In the wake of the ABM Treaty's dissolution, Russia initiated the development of six new nuclear delivery systems including a nuclear-armed, nuclear-powered cruise missile; a nuclear-armed underwater drone; and maneuvering hypersonic missiles. A common feature of these systems is that they are designed to evade or penetrate strategic missile defenses, a fact that lends credence to Russian statements that these programs were initiated specifically to respond to the US withdrawal from missile defense constraints and to hedge against US progress in fielding these systems (Putin 2018).

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While these new delivery systems do not alter the essential strategic calculus — Russia's ballistic missiles were already able to evade or overwhelm existing and proposed US missile defenses — they do present a more complicated set of technologies for both countries to manage. Although Russia states that it is prepared to include two of these systems — the Avangard maneuvering hypersonic missiles, which are launched from ICBMs, and the Sarmat "heavy" ICBM[12] — under existing New START rules for counting missiles (Tass 2019), the other systems would have to be addressed separately in any future agreements.

Missile defense is a more immediate consideration for China. Because China fields so many fewer nuclear weapons than the United States (or Russia), US missile defense systems are already a considered a major challenge to Beijing's ability to retain an assured second-strike capability and thus are likely to be a driving factor for its nuclear planning (Zhao 2020a). Missile defense is not the only external factor, of course. US nuclear doctrine and strategic posture more generally are also key concerns. For example, the United States does not explicitly accept mutual vulnerability with China, and, unlike China, it has not adopted a policy of "no first use" of nuclear weapons. The capability of the United States to conduct a nuclear or conventional first strike against Chinese nuclear weapons or command-and-control facilities has grown in effectiveness, and the Trump MDR highlights the deliberate integration of offensive and defensive strategies. China fears that US missile defenses could effectively intercept any Chinese nuclear

11. For example, in 2015, Russia's ambassador to Denmark warned in an opinion piece that Denmark's ships faced Russian nuclear retaliation if Denmark joined the "American-controlled" NATO missile defense system in Europe (*Local* 2015).
12. The Avangard hypersonic glide vehicle would be launched from an ICBM and then maneuver through the atmosphere toward its distant target. Current ballistic missile defense sensors and interceptors are not designed to counter these kinds of missiles. The Sarmat launcher can reportedly carry up to 10 MIRVs (Kristensen and Korda). Since at least one hit-to-kill missile defense interceptor would be needed to target each MIRV, this can rapidly create a bigger burden on the defense than the offense.

forces left after a first strike or may fear that the United States believes this to be true and so may have an incentive, however small, to strike first.

Currently, China fields approximately 116 land-based ICBMs and submarine-launched ballistic missiles that could reach the United States (Kristensen and Korda 2019). While China deploys a small number of nuclear-armed submarines, these subs are unlikely to get close enough to the US coast to use their missiles on the continental United States before being detected and intercepted (Glaser and Fetter 2016). Until and unless China moves to a launch-on-warning posture, it also would not count on its silo-based ICBM force surviving a first US strike. Thus, the credibility of China's retaliatory capability rests mainly on its relatively small mobile ICBM force, around 48 missiles. Because of increasingly capable US space-based intelligence, surveillance, and reconnaissance systems, China must also consider that not all of these missiles would survive a US first strike that tried to eliminate them (Glaser and Fetter 2016). So while US strategic missile defense systems are nominally sized to counter a small number of North Korean missiles, they will also have significant capability against the relatively small number of Chinese retaliatory missiles expected to survive a US first strike.

There is no evidence to suggest that the US pursuit of the GMD system has had any dissuasive effect on North Korea or Iran.

This risk to its deterrent is held by Chinese analysts to be the most important external driver of China's efforts to modernize its arsenal (Zhao 2020b). As with Russia, many of the technical choices China is making support this assessment, including the pursuit of technologies designed to evade or overwhelm missile defenses, including equipping their ICBMs with MIRVs and penetration aids (US DoD 2015).

As US investments in strategic missile defenses continue and especially if the technologies, sizes, and locations of the defenses make them relevant to defeating Russian and Chinese ICBMs, Russia and China may fear the United States may one day believe it has a credible first-strike capability. This fear, and the dynamic of Russia and China modernizing their arsenals and building more-sophisticated systems to evade or overwhelm missile defenses will be a central issue for the coming decades.

For its part, the United States seems prepared to participate in this arms race. The Trump MDR frames the Chinese and Russian development of hypersonic glide and cruise missiles and other systems designed to overcome ballistic missile defenses as emerging threats against which the United States needs to build new defenses, rather than steps taken to hedge against an unconstrained US missile defense program. Without intervention, this path leads to a cyclical, expensive, and dangerous buildup of offense and defense.

MISSILE DEFENSE AND PROLIFERATION

Many factors will inform an emerging missile state's decision on whether it will pursue an ICBM capability, including its expectations about whether such a capability can contribute to meeting its strategic goals and what the costs would be. The state may have a fairly low bar for such a program. Its goal might be met by simply demonstrating a credible ability to deliver a single long-range nuclear weapon to its potential adversary's territory if it believes that this capability would be intolerable to its adversary. In such a case, a marginally effective missile defense system, or even one with unknown effectiveness, may have little effect on the cost-benefit calculation. Or it could even create an incentive to build more or more-sophisticated missiles. There is no evidence to suggest that the US pursuit of the GMD system has had any dissuasive effect on North Korea or Iran. The bulk of North Korean long-range missile testing has taken place after the GMD's initial deployment in 2002.

To alter this calculation, the missile defense system would need to be very effective. More to the point, the emerging missile state would need to perceive it to be so, based on observable evidence. This has been a challenge in the current best example, the US GMD system. Despite an essentially unconstrained budget (more than $45 billion and counting), the system has not demonstrated a credible ability to defend in a real-world scenario, in particular, one that includes the types of countermeasures a dedicated adversary would have available. Because North Korea's is a relatively small peninsular country, it has been suggested that a focused boost phase missile defense system based on ships or aircraft in international waters or airspace might be a more effective solution. As mentioned above, it has not been clear that such a system would be supported by existing technology.

FUTURE TRENDS

It is of course quite challenging to guess how technology will evolve beyond a decade or two. The competition between missile defenses and a well-prepared offense advantages the offense. That is unlikely to change in the future. It has long been the assessment of the intelligence community that states capable of building ICBMs should be able to build effective countermeasures.[13] A country with an offensive capability also would have the advantage of being able to monitor its adversary building and testing a missile defense system because the attributes and locations of system components, such as radars and missile silos, are observable and tests are difficult to conceal. The first country could then adjust its planning in response to its observation of its adversary's progress.

While China and Russia have long been assessed to have developed effective missile defense countermeasures, in the coming years, they may gain more confidence in their ability to overcome US defenses as they continue to gain experience with their own midcourse defense technology. However, it is not clear this would allay Chinese and Russian fears about US missile defenses. The nature of military planning is to hedge against an adversary's future advances, and the conservative path for Russian and Chinese planners may well give weight to a simple interceptor-to-missile ratio, assuming that the United States will eventually make a technical breakthrough to mitigate its missile defense's vulnerability to countermeasures. And technical assessments are only part of the mix; political judgments and industrial interests also will have a voice.

It is also conceivable that technical advances will eventually permit the United States to field geographically limited systems that could provide defense against North Korean missiles sufficiently capable that Washington would then consider circumscribing the development of the GMD and Aegis systems. While entrenched bureaucratic and economic interests are likely to provide a huge barrier to the United States setting aside existing programs, a deepening economic crisis or pushback by civil society against excessive military spending may force hard choices. That might be enough to keep the United States from developing new systems such as space-based interceptors. Although technological advances are likely to make space-based missile defense systems, including both sensors and interceptors, more economical, they will still be expensive to scale up. If current trends continue, anti-satellite weapons will continue to proliferate and become more sophisticated (unless constrained by agreement), and it is unlikely that a controversial system such as a space-based missile defense will operate uncontested, making such an investment even more unattractive.

It also seems unlikely that the United States would abandon its missile defense programs because the North Korean threat was assessed to be too mature to counter. It is more likely that these missile defense systems would then be refocused on a different threat in the way that the United States pivoted from defending against the Soviet arsenal to the emerging Chinese missile threat and then

13. The 1999 US National Intelligence Estimate assessed that Russia and China had already developed numerous countermeasures and that emerging missile states could deploy penetration aids and countermeasures by the time they flight-tested their missiles (Walpole 1999).

to other emerging missile states. In the same vein, a significant advance in the Iranian missile program with an unambiguous focus on ICBM development may provide additional incentives for the United States to expand its program.

CONCLUSIONS

Given its history, the United States will find it difficult to let go of the alluring possibility that vulnerability to nuclear weapons can be addressed by complex technical solutions. If current trends hold, strategic missile defense programs will continue to be well-funded for this reason and because of entrenched political and industrial interests. But the enormous investments will likely yield incremental rather than decisive improvements. The limited capabilities of the systems will not bring expected advantages, but China and Russia will find it difficult not to respond. (Entrenched political and industrial interests are important for these states as well.)

There are a few paths that might enable a breaking away from this offense-defense dynamic. Because so much of this cycle is predicated on perception or misperception of capability and intent, it is possible that a rigorous appraisal by these states, individually or jointly, of the technical prospects and strategic effects of existing and proposed missile defense systems could help break the cycle of nuclear buildup and soften the ground for nuclear reductions. There is a long history of efforts in the United States by national academies, professional societies, and other nongovernmental analysts to provide unclassified analysis that can support a robust public conversation. For example, the aforementioned 2012 National Academies study (National Research Council 2012), drawing on work by the American Physical Society in 2004 (Barton et al. 2004), laid out clearly the challenges and costs of boost phase missile defense systems, and a 2000 study organized by the Union of Concerned Scientists and the Massachusetts Institute of Technology (Sessler et al. 2000) established clearly that countermeasures to midcourse missile defenses would be a formidable obstacle to success of such systems. When the conditions are right, such efforts have helped shape the debate and decisions. Analysis by trusted technical experts could set clear boundaries on what role strategic missile defense is likely to play in US security.

As Russia and China gain their own experience in developing missile defense systems, their own technical appraisals could help avoid unnecessary reaction to a limited US capability. And, as suggested by Tong Zhao, independent experts from the United States and China could conduct an open-source joint study of the feasibility of constructing a defense against North Korean long-range missiles that minimizes the effects on China (Zhao 2020b). Such a study could identify the most useful possibilities, or it could establish that such a system is difficult or impossible to construct. That might at least mitigate Chinese suspicions about US programs.

Additionally, the United States could focus its efforts solely on those systems that can be most clearly distinguished as regional systems. This may be by unilateral choice or preferably by negotiated constraint, as part of a new round of nuclear reductions.

Strategic missile defense, despite decades of effort and billions of dollars spent, has yet to provide a reliable defense against a limited missile threat, much less contend with what a sophisticated adversary might field. A simpler and cheaper approach to reducing vulnerability to nuclear weapons is to accept limits on strategic defenses of dubious value to secure significant limitations on offensive weapons. ■

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BIOGRAPHY

Laura Grego is a senior scientist in the Global Security Program at the Union of Concerned Scientists. She focuses her analysis and advocacy on the technology and security dimensions of ballistic missile defense and of outer space security. She has authored or co-authored numerous papers on a range of topics, including cosmology, space security, and missile defense, and has testified before Congress and addressed the UN General Assembly and the UN Conference on Disarmament on space security issues. Dr. Grego is a technical advisor for the Woomera Manual on the International Law of Military Space Operations project. She also serves as associate editor of Science and Global Security, and as a delegate to the American Physical Society's Panel on Public Affairs for the Forum on Physics and Society.

Before joining UCS, Dr. Grego was a postdoctoral researcher at the Harvard-Smithsonian Center for Astrophysics. She earned a PhD in experimental physics at the California Institute of Technology, and a BS in physics and astronomy at the University of Michigan. An expert source for print, radio, TV, and online news, Dr. Grego has been cited by the Boston Globe, Chicago Tribune, Los Angeles Times, New Scientist, New York Times, Washington Post and USA Today, and has appeared on CNN, Fox News, the Discovery Channel, and NPR.