Arms Control Tomorrow

Strategies to Mitigate the Risks of New and Emerging Technologies

Shannon Bugos

An Arms Control Association Report

May 2023

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COVER PHOTO: A U.S. missile combat crew commander performs a simulated key turn of the Minuteman III intercontinental ballistic missile (ICBM) system during a Simulated Electronic Launch-Minuteman (SELM) test inside the launch control center (LCC) at a missile alert facility in Nebraska on April 11, 2017. (U.S. Air Force photo/Staff Sgt. Christopher Ruano)

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About the Author

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The author is responsible for the content of the report. The statements made and views expressed do not necessarily represent the views of the Arms Control Association Board of Directors or the members of the Association, the German Federal Foreign Office, or the European Leadership Network.

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ABOUT THIS REPORT

This report marks the culmination of the Arms Control Association's project titled "Arms Control Tomorrow." This work constitutes part of a project by the European Leadership Network, with funding from the German Federal Foreign Office, called "Unpacking Technological Complexity and Approaches to Nuclear Policy Formulation." The association's work fell within strand four of the project, titled "Mitigation Strategies and Arms Control."

The association's project focused on new or existing arms control and risk reduction measures, which decision-makers could propose and support, to prevent new and emerging technologies with military uses from leading a conflict or confrontation into nuclear war. The project took place from March 2021 through December 2022. The association hosted five virtual workshops, each centered on one of the selected technologies, except for the last, which combined drones and lethal autonomous weapon systems, and including 12 to 20 participants. The participants included former government officials and diplomats, policy experts, and technical experts from across the world.

Each workshop was split into two parts: one focused on defining a particular technological capability and the risks that capability might pose to strategic stability, and the other focused on the possible arms control and risk reduction measures to mitigate the identified risks. Following the presentations, the participants broke into small groups for further detailed discussion. The workshops were conducted under the Chatham House Rule. This report reflects the content of those valuable, informative discussions, for which the association is deeply grateful.

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Executive Summary

Over recent years, the topic of new and emerging technologies with military applications has ignited a dynamic debate among defense officials, political leaders, diplomats, policy experts, and technical experts. Although some view these technologies as offering a marked, game-changing battlefield advantage for those who employ them, others deem such an assessment as an exaggeration or call for increased attention on the risks of their use.

This report provides an overview of the potentially destabilizing effects of several new and emerging technologies and their respective military applications. It aims to provide decision-makers with a better understanding of how to mitigate the risks and reduce the chances that a major power conflict or confrontation escalates to the nuclear level through a range of arms control and risk reduction measures.

Throughout this report, the term "new and emerging technologies" references the wide range of scientific and technical developments that if applied in the military sphere, could have a transformative impact on the future of warfare in unpredictable and potentially hazardous ways. This report focuses on six significant, distinct emerging military capabilities: hypersonic weapons systems, direct offensive cyberoperations, offensive counterspace capabilities, artificial intelligence (AI)-enabled capabilities, drones, and lethal autonomous weapons systems (Box ES.1). These capabilities were selected based upon two factors. First, they have already entered or will enter the field within about the next 10 years. Second, governments and civil society have already begun to convene in various forums to begin discussions on the battlefield effects of these capabilities and to chart potential avenues for arms control and risk reduction.

This report distills information and ideas from a series of workshops, involving dozens of technical and policy experts in each technology area, that the Arms Control Association conducted in 2021 and 2022. It identifies four overarching themes that highlight the greatest concerns over how the military employment of new and emerging technologies might increase the risk of nuclear weapons use.

Increasing the pace of conflict. The use of new and emerging technologies in a conflict or confrontation could speed up the pace of either to a dangerous extent, with the involved parties moving quickly up the escalation ladder. This theme covers two primary risks: less time for decision-makers to choose their country's next move and the information overload of decision-makers.

Increasing uncertainty. New technological capabilities with military uses could increase overall uncertainty during a conflict or confrontation, such as the nature of the operation and the intentions of an adversary. The capabilities also could expose new vulnerabilities, cause uncertain effects, and introduce new actors who operate in unknown ways.

Reducing the human role. With the bigger pool of intelligence, surveillance, and reconnaissance information and other data provided by AI-enabled systems, overwhelmed political and military decision-makers may task AI-enabled capabilities with collecting and processing information across the battlefield domains, assessing the various courses of

A U.S. military aide carries the "nuclear football," which contains launch codes for U.S. nuclear weapons, on October 3, 2022, in Washington, DC. (Photo by Drew Angerer/Getty Images)

Box ES.1 - The Six Selected New and Emerging Technological Capabilities

Hypersonic Weapons

A hypersonic weapon refers to a missile or vehicle that travels at speeds at least five times the speed of sound, or at Mach 5.

Direct Offensive Cyberoperations

An offensive cyberoperation is a hostile activity against an adversary computer system that aims to compromise the confidentiality, integrity, or availability of information handled by that computer.

This report focuses on operations specifically targeted against computer systems anywhere in the nuclear enterprise.

Offensive Counterspace Capabilities

Offensive counterspace capabilities are capabilities aimed at deceiving, disrupting, denying, degrading, or destroying space systems.

This report focuses on anti-satellite capabilities that include both direct-ascent systems and co-orbital capabilities.

Artificial Intelligence-Enabled Capabilities

Artificial intelligence serves as an umbrella term, encompassing a variety of computation techniques and enabling technologies that give way for computers to solve complex problems previously handled only by humans.

This report focuses on the application of AI for military or warfighting purposes.

Drones

A drone refers to a vehicle that does not have a pilot, crew, or passengers on board and that is usually autonomous, controlled from a ground station, or given a preprogrammed mission. This report focuses on aerial and underwater drones.

Lethal Autonomous Weapons Systems

A lethal autonomous weapons system is a weapons system that selects targets and employs force against targets without human intervention.

action, determining the best possible outcome, and perhaps even recommending a particular choice and executing that response. This redistribution of control could result in little to no substantial, effective human oversight.

Incentivizing arms racing. An arms race of new and emerging technologies is arguably already underway, with the potential to ramp up even further in quantitative and qualitative ways as actors quickly pursue and deploy new, cutting-edge capabilities in an attempt to preserve or gain a strategic advantage.

Decision-makers can take action to mitigate these risks in the near and long term. Risk reduction and arms control efforts should focus on pursuing multiple measures across domains and technologies and among governmental and nongovernmental actors that, taken altogether, create an effective, feasible, and sustainable arms control regime.

This report identifies near-term risk mitigation measures that are likely achievable now or within the next five years: crisis communications systems, definition establishment, norms, unilateral declarations and actions, and confidence-building measures. These types of measures can help enhance transparency and prevent misperceptions, establish a shared language for the technologies recognized by the world's majority, and create accepted standards for responsible behavior in use of a capability.

This report outlines long-term measures that are achievable within the next 10 years or beyond: arms control and risk reduction arrangements (e.g., treaties, agreements) that involve more than one country and are more formal than confidence-building measures, although not necessarily legally binding.

The military capabilities and applications enabled by new and emerging technologies examined in this report not only exacerbate existing and create new risks to strategic stability and international security, but also make efforts to mitigate such risks and pursue effective arms control of these systems all the more complex. Given the potential adverse effects of new and emerging military technologies, policymakers can and should consider near-term arms control and risk reduction measures. These measures could lay the foundation for long-term measures that help build a future security architecture that individually but even more so together offers transparency, predictability, and stability and pushes the prospect of nuclear war farther out of the realm of possibility.

Chapter 1

First Principles for 'New' Technologies, Arms Control, and Strategic Stability

In recent years, the topic of new and emerging technologies with military applications has ignited a dynamic debate among defense officials, political leaders, diplomats, policy experts, and technical experts. Although some view these technologies as offering a marked, game-changing battlefield advantage for those who employ them, others deem such an assessment as an exaggeration or call for increased attention on the risks of their use.

"Russia's advanced arms are based on the cutting-edge, unique achievements of our scientists, designers, and engineers," boasted Russian President Vladimir Putin in his well-known 2018 address to the Federal Assembly.[1] He described intercontinental uncrewed underwater vehicles that can travel at "extreme depths" and at "a speed multiple times higher than the speed of submarines," as well as new, "extremely powerful" hypersonic weapons that provide "substantial advantages in an armed conflict" and are "invulnerable" to missile defenses. The United States, for its part, has referred to new and emerging technologies as those that will "ensure we will be able to fight and win the wars of the future."[2]

"AI [artificial intelligence] technologies will be a source of enormous power for the companies and countries that harness them," concluded the U.S. National Security Commission on Artificial Intelligence in 2021.[3] "States, criminals, and terrorists will conduct AI-powered cyber attacks and pair AI software with commercially available drones to create 'smart weapons.'"

These technologies hold the potential to change the tempo and the tools of warfare and to undermine adversary military offensive and defensive capabilities more quickly, efficiently, and accurately. The new capabilities could also help stabilize a conflict or confrontation, such as by enhancing intelligence, surveillance, and reconnaissance tools and by allowing systems to operate in communications-degraded or -denied environments inaccessible to traditional systems.[4]

Yet, some caution that these technologies might not significantly alter a conflict or confrontation. Russia employed new Kinzhal hypersonic air-launched ballistic missiles in Ukraine in March 2022, marking the first use of new hypersonic weapons systems in warfare. U.S. Gen. Mark Milley, Joint Chiefs of Staff chairman, remarked in May 2022 that the multiple uses of Kinzhal missiles by that time had not led to a major shift in the war in Russia's favor. "Other than the speed of the weapon…we are not seeing really significant or game-changing effects to date with the delivery of the small number of hypersonics that the Russians have used" in Ukraine, Milley acknowledged.[5]

Still others suggest that military application of new and emerging technologies runs the risk of destabilizing a conflict or confrontation and therefore increasing the chances that it leads to nuclear weapons use. These potential risks include decreasing the amount of time for decision-makers to gather information, analyze the intelligence, evaluate response options, and select a response; removing the human component from the operational loop by endowing systems with autonomous functions; and prompting misperceptions of adversary capabilities and intentions, leading to greater chances of catastrophic miscalculation and escalation. The use of multiple technologies across domains could further exacerbate many of these risks.

This report focuses on risks to paint a more comprehensive picture of the potential destabilizing effects of new and emerging technologies and their respective military applications. The report aims to equip decision-makers with a better understanding of how to mitigate the risks and to downgrade the chances that a conflict or confrontation escalates to the nuclear level by proposing a range of arms control and risk reduction measures.

Throughout this report, the term "new and emerging technologies" will refer to a wide range of scientific and technical developments that if applied in the military sphere, could have a transformative

A Russian MiG-31K fighter jet equipped with Kinzhal hypersonic missiles flies over Moscow during a parade in 2018. (Photo by Sefa Karacan/Anadolu Agency/Getty Images)

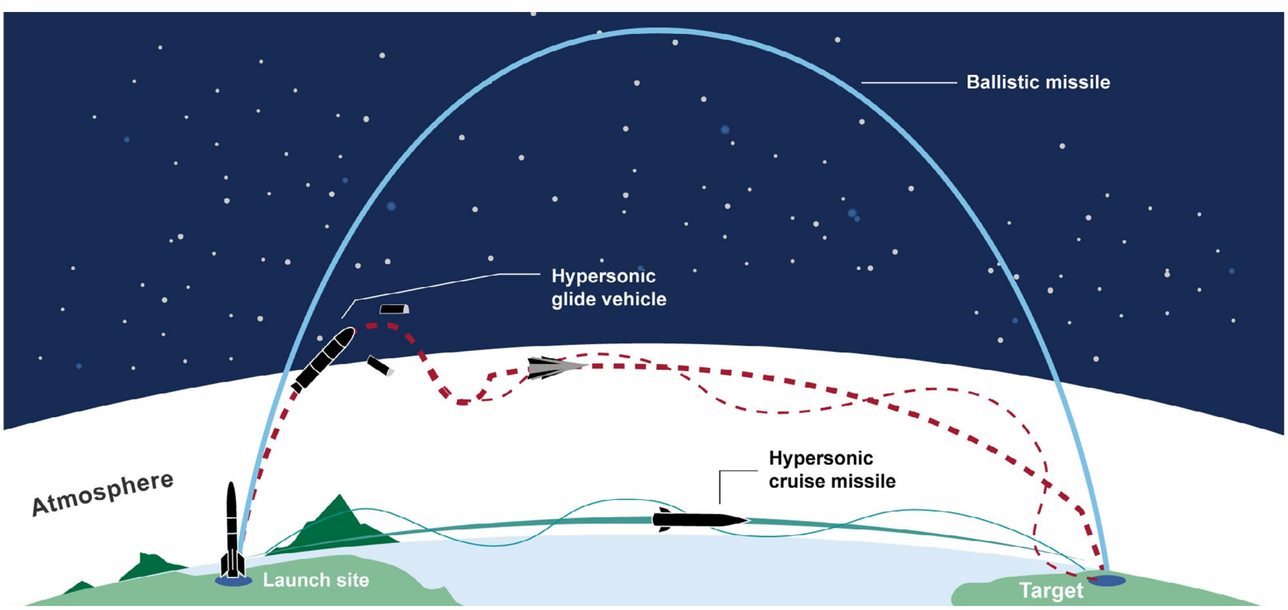
impact on the future of warfare in unpredictable, potentially hazardous ways.[6] It spotlights six significant emerging technologies with potentially destabilizing military uses: hypersonic weapons systems, direct offensive cyberoperations, offensive counterspace capabilities, AI-enabled capabilities, drones, and lethal autonomous weapons systems (LAWS). Two factors informed the selection of these capabilities. First, the selected capabilities have already or will enter field service within about the next 10 years. Second, governments and civil society have already begun discussions in various forums on the battlefield effects of these capabilities and on potential avenues for arms control and risk reduction.

Some of these capabilities are not particularly new but rather operate in new situations or have new military applications. For instance, the space domain has long existed. China's current program on direct-ascent anti-satellite (ASAT) capabilities has roots in the 1960s, while the United States and the Soviet Union each had multiple counterspace programs running during the Cold War.[7] The most notable change with counterspace capabilities relates not necessarily to the capabilities themselves but rather to the circumstances that incentivize their development, deployment, and use.[8] A handful of AI applications for civilian and military use similarly have existed since the 1960s, with the field going through several ups and downs over the decades.[9]

New and emerging technologies do not need to have a nuclear application or capability in order to potentially affect the nuclear domain and upset strategic stability. Drones employed for nonlethal intelligence, surveillance, and reconnaissance missions might help to find a nuclear-armed country's second-strike nuclear forces, which derive their value from evading detection and surviving a first nuclear strike.

Based on a series of workshops with technical and policy experts, this report determines that the military employment of new and emerging technologies might increase the risk of nuclear weapons use by speeding up the pace of conflict, creating greater uncertainty, minimizing human control, and incentivizing arms racing. Decision-makers could take action to

Figure 1.1 - Trajectory of Hypersonic Weapons Systems



Ballistic missiles follow a largely predictable, arched trajectory, flying high above the atmosphere before plummeting back toward Earth. Hypersonic glide vehicles and cruise missiles fly at lower altitudes within the atmosphere and follow different flight paths. (Illustration by U.S. Government Accountability Office)

A U.S. MQ-9 Reaper surveillance and attack drone aircraft lands during a training program.
(Photo by Rick Loomis/Los Angeles Times via Getty Images)

mitigate these risks through efforts such as building a shared language around these technologies, creating responsible rules of the road, and pursuing more formal arms control arrangements among governmental and nongovernmental actors.

Below are working definitions of each of the six selected new and emerging technologies. Details of the methodology behind the project follow in this chapter.

The second chapter elaborates on the four themes that emerged throughout the workshop conversations on potential risks to strategic stability: an increased pace of conflict, increased uncertainty, less human control, and incentivized arms racing. Various specific risks to strategic stability fall within each theme.

The last chapter presents near- and long-term, formal and less formal arms control and risk reduction measures that decision-makers could pursue to mitigate the aforementioned risks and to bolster strategic stability. This chapter serves as a tool kit, detailing the options available for responsible actors developing, deploying, and employing these technological capabilities to avoid an outbreak of nuclear war.

Definitions

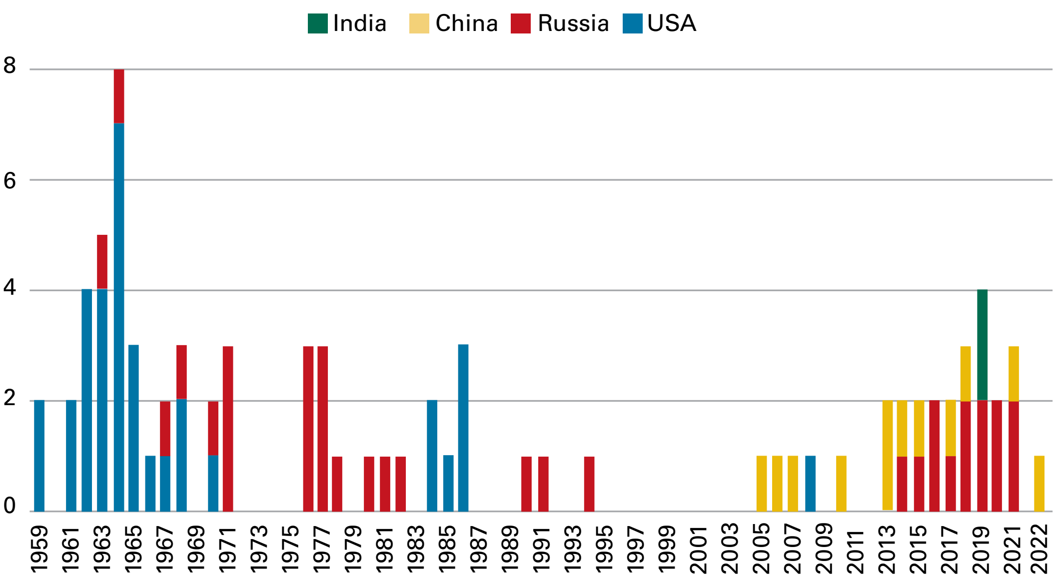
Hypersonic weapons systems. A hypersonic weapons system is a missile or vehicle that travels at speeds at least five times the speed of sound.[10] The appeal of these weapons stems from their unique flight profile of flying at lower altitudes than intercontinental ballistic missiles (ICBMs) and greater altitudes than traditional cruise missiles, in combination with high speeds, greater maneuverability, and stealth (Figure 1.1).

This report focuses on two types of hypersonic weapons capabilities. The first type features hypersonic boost-glide weapons, which reenter the atmosphere fairly quickly after launch and then can glide for long distances. The second type includes air-breathing vehicles such as hypersonic cruise missiles, which are aerodynamically supported throughout their entire flight and typically feature a high-speed scramjet propulsion system. China, Russia, and the United States have the most advanced development programs for hypersonic weapons systems.

Direct offensive cyberoperations. An offensive cyberoperation is a hostile activity against an adversary computer system that aims to compromise the confidentiality, integrity, or availability of information handled by that computer system.[11] A breach of confidentiality results in unauthorized parties seeing data. A breach of integrity results in improper alteration or erasure of data or programs. A compromise of availability means the data or services of a computer are unavailable to authorized users. The detection of an attacker provides little to no information about the attacker's intent, specifically, whether the attacker wishes to exfiltrate information (a breach of confidentiality) or to cause damage (a breach of integrity or a compromise of availability).

This report uses the term "direct offensive cyberoperations" to refer to operations specifically

Figure 1.2 - ASAT Tests by Year



Source: Louison Mazeaud, "History of ASAT Tests in Space," Secure World Foundation, February 22, 2023, https://swfound.org/counterspace.

targeted against computer systems anywhere in the nuclear enterprise: the nuclear explosive devices (warheads); the platforms and delivery vehicles that carry warheads to their targets; nuclear command, control, and communication (NC3) systems; and nuclear weapons support infrastructure.

Offensive counterspace capabilities. Offensive counterspace capabilities refers to capabilities aimed at deceiving, disrupting, denying, degrading, or destroying space systems. This report focuses on ASAT weapons systems that include both direct-ascent systems, which are launched from the ground, air, or sea to damage satellites kinetically, and co-orbital capabilities, which are placed into the same orbit as their target and maneuvered to approach the target and attack by various destructive or nondestructive means.[12]

The actors in space include those that have, for instance, conducted destructive ASAT weapons testing: China, India, Russia, and the United States (Figure 1.2). Countries developing counterspace capabilities include Australia, France, Iran, Japan, North Korea, South Korea, and the United Kingdom.

AI-enabled capabilities. AI does not refer to any particular, verifiable technology. Rather, AI serves as an umbrella term encompassing "a wide set of computation techniques and enabling technologies, which allow computers and robots to solve complex, seemingly abstract problems that previously yielded to human cognition."[13] Two related terms include

Box 1.1 - Key AI-Related Terms

Automation

Automation refers to systems that mechanically respond to sensory input and step through predefined procedures, and whose functioning cannot accommodate uncertainties in the operating environment. An example of this is a robotic arm used in the manufacturing industry.

Autonomy

Autonomy can be described as a complex form of automation that allows a machine to execute a task or tasks using explicit or implicit programming rules and without human intervention.

Machine Learning

Machine learning is a key enabler of the AI renaissance, as it is an approach to software development that first builds systems that can learn and then teaches them what to do using a variety of methods (e.g., supervised learning, reinforcement learning, or unsupervised learning).

Machine learning involves "automatic reparameterization and partial reprogramming" and can be used to design systems that work in an autonomous way.

Source: Vincent Boulanin et al., "Artificial Intelligence, Strategic Stability and Nuclear Risk," Stockholm International Peace Research Institute, June 2020, p. 15, https://www.sipri.org/sites/default/files/2020-06/artificial_intelligence_strategic_stability_and_nuclear_risk.pdf machine learning, referring to the algorithms enabling AI developments, and autonomy, which is a by-product of AI (Box 1.2). This report focuses on the application of AI for military or war-fighting purposes, including those used for command, control, communications, computers, intelligence, and reconnaissance, such as early warning and intelligence gathering, and the surveillance, capture, disabling, or striking of human and material targets.[14]

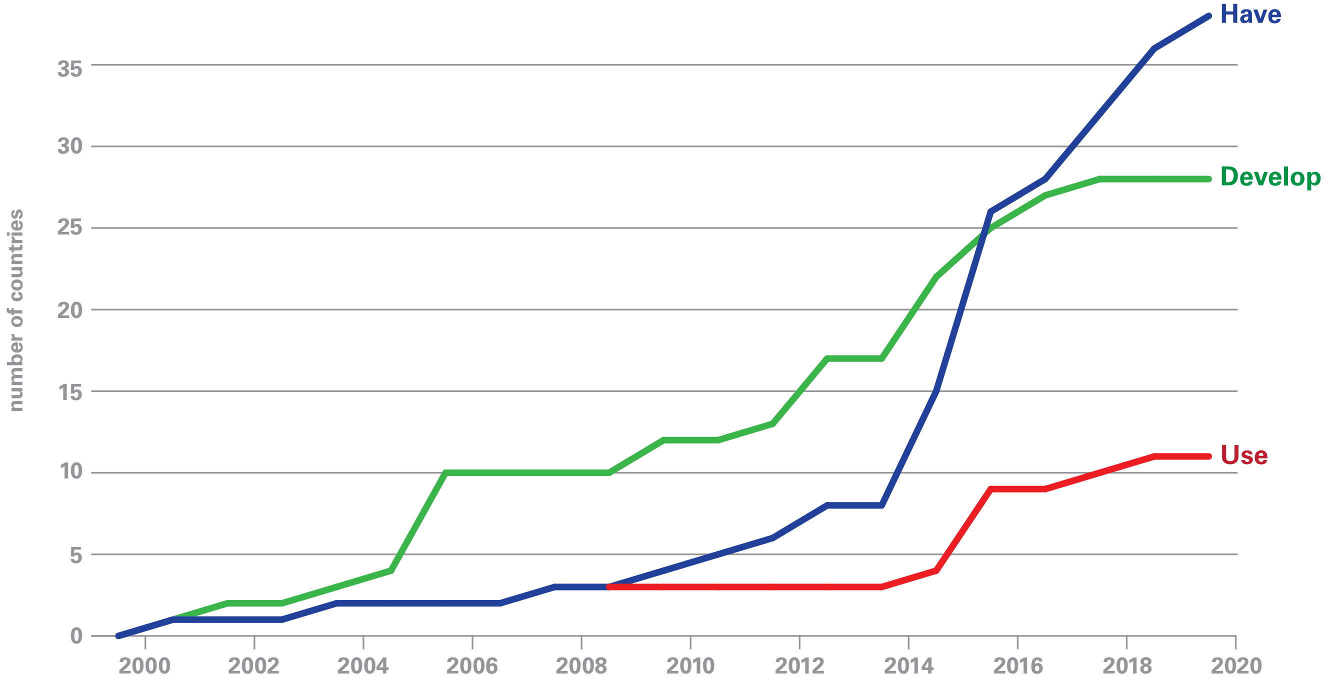
Drones. A drone refers to a vehicle that does not have a pilot, crew, or passengers on board and is usually autonomous, controlled from a ground station, or given a preprogrammed mission. This report focuses on aerial and underwater drones.

In general, drones have three types of missions: nonlethal intelligence, surveillance, and reconnaissance (ISR) missions; combat missions, which can be lethal and involve tasks such as providing close air support to troops on the ground and conducting strikes on specific targets; or both. The primary drone producers are China, Israel, Turkey, and the United States, while the top importers are India and the United Kingdom (Figure 1.3).

Lethal autonomous weapons systems. LAWS "select and apply force to targets without human intervention. After initial activation or launch by a person, an autonomous weapons system self-initiates or triggers a strike in response to information from the environment received through sensors and on the basis of a generalized 'target profile.' This means that the user does not choose, or even know, the specific target(s) and the precise timing and/or location of the resulting application(s) of force."[15]

China's ATB-001 system, a high-altitude, long-endurance uncrewed aerial vehicle intended for intelligence, surveillance, and reconnaissance and strike missions, performs during an airshow in 2022 in China.
(Photo by VCG via Getty Images)

Figure 1.3 - The Number of Countries That Have Developed, Acquired, and Used Armed Drones Over Time



Source: Peter Bergen, Melissa Salyk-Virk, and David Sterman, "World of Drones," New America, July 30, 2023, https://www.newamerica.org/international-security/reports/world-drones/.

Some experts, however, suggest understanding LAWS less through a definition based on technical characteristics and more through a functional perspective, which centers on viewing the weapon as a machine with autonomy in its critical functions.[16] The latter approach calls for greater scrutiny on the relationship between human and machine to assess the potential loss of meaningful human control but without getting caught up in the exact technical characteristics. The main developers of LAWS are China, Israel, Russia, and the United States.

Strategic stability. Strategic stability exists when nuclear-armed countries perceive neither an incentive to conduct a nuclear first strike, known as crisis stability, nor an incentive to build up their respective strategic nuclear forces, known as arms race stability. This means that the chances of nuclear conflict or confrontation, whether accidental or inadvertent, are minimized.

Arms control and risk reduction. Both arms control and risk reduction measures aim to decrease the risk of nuclear weapons use and strengthen strategic stability. Arms control refers to a more official form of mutual agreement or commitment, and risk reduction refers to more informal voluntary actions, joint statements, or agreements. Although traditional arms control refers to legally binding treaties, arms control has become a broader concept to integrate new and emerging nuclear and non-nuclear military capabilities and technologies, to encompass a wider range of initiatives that reduce risk, and to consider limitations or reductions across different domains.[17]

The process of arms control is time consuming because it involves direct dialogue among diplomatic, political, and military officials from the involved actors; exchanges of information; the expression of unilateral stability and security concerns and the identification of mutual concerns; and many rounds of dialogue to hammer out the agreement's details. Yet, the process itself can help reduce tensions by building trust and maintaining relationships between the involved parties.

Arms control may prove difficult to achieve because some of the relevant novel military technological capabilities defy categorization, although moving away from the traditional form of equal numerical limits and toward broader like-for-like exchanges could make it more achievable. Nevertheless, risk reduction measures may ultimately emerge as relatively more attainable.

The U.S. and Russian delegations to the New START negotiations sit opposite one another at the table where many of the negotiating sessions were held in the Russian Mission to the United Nations in Geneva. (U.S. Mission Photo: Eric Bridiers)

Chapter 2

Strategic Stability Risks Posed by New and Emerging Technologies

During the project's workshops on the selected new and emerging technological capabilities, technical and arms control experts identified a plethora of possible ways in which the use of the capabilities in a conflict or confrontation could increase the likelihood of nuclear escalation. The project leaders focused on the potential risks to strategic stability that the workshop participants mentioned repeatedly and with great concern with regard to one or more of the technologies. From those risks, four themes emerged.

New and emerging technologies could threaten strategic stability and increase the possibility of nuclear weapons use by way of

- increasing the pace of conflict,
- increasing uncertainty,
- reducing the human role, and
- incentivizing arms racing.

This report focuses on the potential risks to strategic stability, but acknowledges that new and emerging technologies could also benefit strategic stability, such as by strengthening situational awareness and early warning in high-risk, time-critical conflicts; improving verification tools; and lowering the dangers for human operators. Further detail on the four themes and the risks that fall within them are below.

Increasing the Pace of Conflict

The use of new and emerging technologies in a conflict or confrontation could escalate the pace of either to a dangerous extent, with the involved parties moving quickly up the escalation ladder. The workshop participants identified two related risks that fall under this theme: less time for decision-makers to choose their country's next move and the information overload of decision-makers. With less time in which to make a decision and an overwhelming amount of information to process during such a high-pressure time crunch, decision-makers may act rashly, calling the shots more out of panic than strategic thinking, especially if they are under the perception that their country's nuclear second-strike forces are under imminent threat.

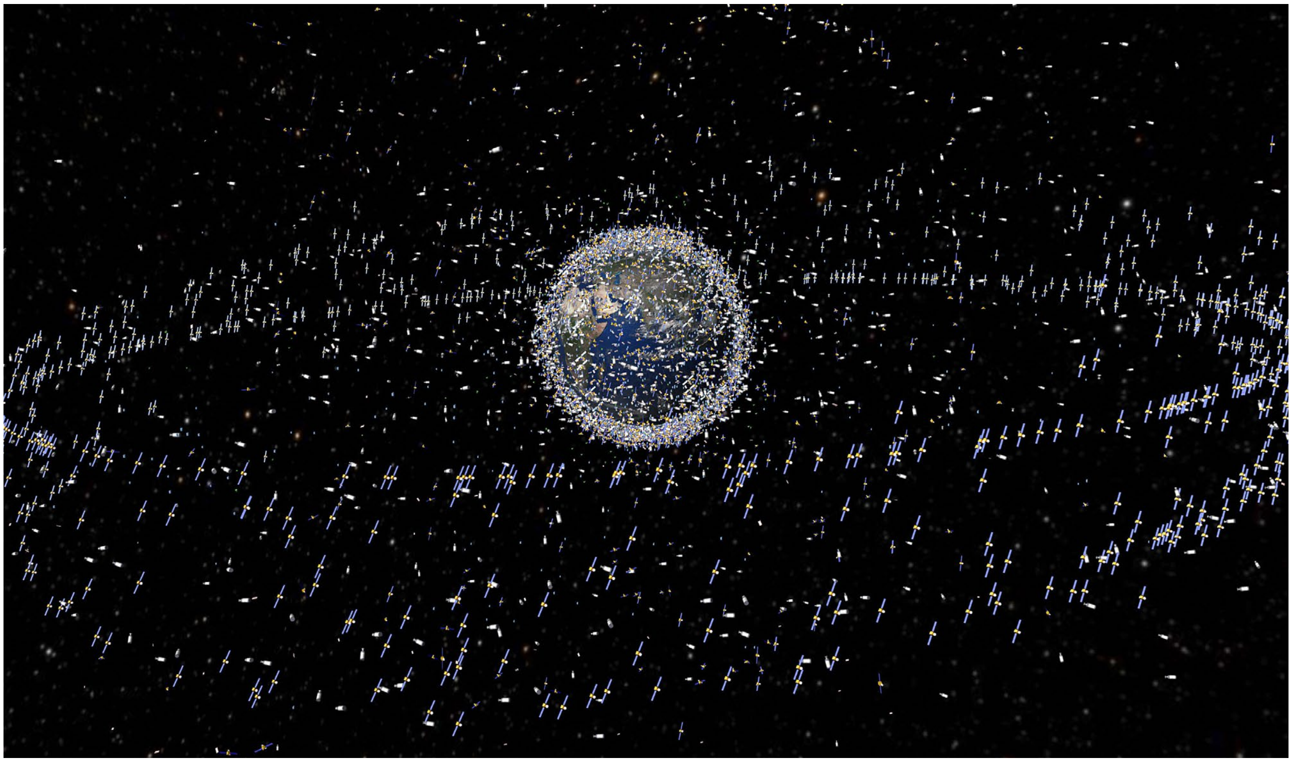
The time frame afforded decision-makers can shrink due to the unique flight profile of new hypersonic boost-glide vehicles and cruise missiles, moving at high speeds and with greater maneuverability to evade early detection. Of particular concern to experts are short- or medium-range hypersonic weapons systems in, for example, a direct confrontation between Russia and NATO in Europe, as compared to hypersonic weapons systems deployed on ICBMs traveling between Russia and the United States.[18]

A targeted country with AI-enabled systems used to gather data and intelligence may also have further information about the unfolding situation at its disposal. Although additional information can improve understanding, the tight timeline might not allow sufficient time for the targeted country to verify its legitimacy and accuracy, analyze all of it through a human lens, and draw conclusions on the nature of an incoming attack. These circumstances lead to higher chances of worst-case scenario assumptions or miscalculation, which could give way to nuclear escalation.

This type of scenario might prompt countries to rely on the AI-enabled systems to analyze the trove of information, provide potential response options, and make a recommended course of action. Yet, such a reliance may redistribute too much control away from the human and toward the machine, a risk further detailed below.

Increasing Uncertainty

The use of new and emerging technologies in an offensive operation during a conflict or confrontation could increase various areas of uncertainty, such as



A computer-generated artist's impression released by the European Space Agency depicts an approximation of 12,000 objects in orbit around the Earth. (Photo by ESA/AFP via Getty Images)

the exact nature of the operation and an adversary's intentions behind it, the new vulnerabilities exposed and the uncertain effects caused by the technologies, and the new cast of actors. The uncertainty about the nature of an offensive operation refers to questions about the technical features of the capabilities comprising the strike. For instance, a country on the receiving end of dual-capable hypersonic weapons systems such as those pursued by China and Russia might question whether the incoming weapons carry a nuclear or conventional payload, a particular uncertainty known as warhead ambiguity.[19]

The uncertainty about an adversary's intentions behind an attack refers to questions about their motivation for carrying out the offensive operation and their intended targets. A country targeted by an adversary's hypersonic weapons might struggle to determine whether the maneuverable missiles are aiming for a site that houses conventional or nuclear delivery systems and command and control or, of special concern, a site that houses both. This particular uncertainty is known as target ambiguity.

Those who operate in the space domain similarly struggle with discerning intentions. For example, a shuttle can travel into space to repair a malfunctioning or damaged satellite, but the country owning the shuttle might instead task it with stealing an adversary's satellite, fueling concerns over nonconsensual close approaches between space systems of different owners. Debris from accidents or tests in space could collide with and irreparably damage or destroy satellites, raising concerns that a state could use a debris-creating direct-ascent ASAT weapons test to camouflage a mission actually intended to destroy an adversary's NC3-associated satellite. An additional area of uncertainty stems from the creation by new and emerging technological capabilities of new vulnerabilities with conventional and nuclear military systems and uncertain effects of the technologies in warfare.

AI-enabled persistent overhead monitoring capabilities, while sifting through the massive amounts of data collected, could lead to a greater risk of false positives or negative interpretations. Meanwhile, AI-enabled ISR systems could enhance the search for high-value, road-mobile, nuclear-armed missiles and the detection of nuclear-armed submarines, which have long proved elusive, by making their reliance on an ability to hide more vulnerable.[20] Hypersonic weapons systems could also hold at risk targets that have thus far largely remained out of reach.[21]

Since Russia's full-scale invasion in February 2022, Ukraine has relied heavily on military-

Table 2.1 - Uncrewed Aerial Vehicles in Use in the Russian-Ukrainian War

Class	Type	Russia	Ukraine
Military Grade	Combat	Forpost,[1] Orion (France)	Fury, Punisher, Bayraktar TB2 (Turkey), Phoenix Ghost (U.S.)[2]
	Reconnaissance	Eleron-3, Granat models, Orlan-10, Orlan-30, Tachyon, Zastava[1]	Leleka, PD-1, Spectator, Tupolev 143 (Soviet era), Bayraktar MINI IHA (Turkey), Puma (U.S.)
	Loitering Munition	KUB, Lancet, Shahed-136 (Iran)	Warmate (Poland), Switchblade (U.S.)
Commercial	N/A	DJI Mavic	DJI Mavic, various “dronations”

[1] These models are Israeli design specifications, locally produced under Russian licenses.
[2] U.S. President Joe Biden committed to transferring four heavy, long-range MQ-1C Gray Eagle uncrewed aerial vehicles to Ukraine, but Secretary of Defense Lloyd Austin reneged in June. Following bipartisan Senate lobbying, the decision remains unresolved.

Note: Country of manufacture noted in parentheses if not produced indigenously.

grade and commercial drones, which have proven decisive in bolstering Ukraine’s very unexpected, successful resistance to Russian forces. Commercial drones in particular stand out as a powerful factor to explain the Ukrainian upset (Table 2.1).[22] The use of drones in Ukraine demonstrates how much remains unknown about the exact impacts of new and emerging technologies in conflict, giving rise to greater uncertainty and increased chances of potential miscalculation and worst-case scenario assumptions.

Workshop participants further noted that uncertainty increases as the number of actors in a domain increase, most prominently with respect to the space domain, cyberspace, and drone technology. Over the decades, new actors have sprung up, including new commercial and state players, to support and supply the weaponization of space. For instance, these actors contribute to an increased number of satellites and spacecraft in space, particularly in low earth orbit, which risks space-based capabilities tasked with nuclear support missions colliding with debris or space-based capabilities tasked with commercial or non-nuclear support missions. A state can also rely on space situational awareness (SSA) software and hardware developed by private companies or involve a commercial partner in space wargames (Box 2.1). For example, between 2010 and 2021, the United States signed 100 commercial SSA data-sharing agreements.[23]

The cyber domain also includes state, nonstate, and commercial actors, such as military contractors or ransomware groups. Drones have proliferated rapidly due to lower barriers to entry, such as a lower price tag, as well as to their removal of human operators from the direct line of fire and the ability to refit commercial drones for ISR and combat missions. The number and diversity of actors and stakeholders introduce uncertainty with respect not only to crowding and complicating domains but also to overwhelming arms control and risk reduction efforts with too many voices and too many demands.

Box 2.1 - Key Space Practices

Space Situational Awareness

a robust, geographically dispersed network of ground-based radars and telescopes and space-based telescopes

Space Traffic Management

the tracking and regulation of space objects by international and national institutions to ensure the domain’s safety and sustainability

Source: Brian Weeden and Victoria Samson, eds., “Global Counterspace Capabilities: An Open Source Assessment,” Secure World Foundation, April 2022, pp. xiv, https://swfound.org/media/207350/swf_global_counterspace_capabilities_2022_rev2.pdf.

Reducing the Human Role

With the bigger pool of ISR information and other data provided by AI-enabled systems, there comes the risk that overwhelmed political and military decision-makers may shift more responsibility to the machine.[24] AI-enabled capabilities may be tasked with not just collecting and processing information across the battlefield domains but also assessing the various courses of action, determining the best possible outcome, and perhaps even recommending a particular choice and executing that response.

Relocating nuclear decision-making from humans to machines could prompt a conflict or confrontation to spin out of control as LAWS move quickly up the escalation ladder with little to no substantial, effective human oversight. One analyst described this concept as a "flash war," with machines misinterpreting incoming data and triggering potential nuclear responses. "With this arms race in speed come grave risks," such as "a war that spirals out of control in mere seconds."[25] After all, humans can serve as firebreaks, as evidenced during the 1983 incident in which the Soviet missile detection system signaled an incoming U.S. ICBM nuclear attack, but a Soviet military officer chose not to report the attack to superiors because he believed it to be a computer system error, as was later confirmed.[26]

Machine learning presents its own vulnerabilities. The quality of the algorithms depends on the data on which the system is trained. "If the training data set is not representative, then the system may fail, may perform poorly, or may misinform human decisions and actions by reinforcing existing human biases or creating new ones."[27]

Humans could also cultivate automation bias, in which they overly rely on an autonomous system and assume the data provided by the system are correct when the opposite is true.[28] During the 1983 incident, the Soviet military officer could have not questioned the incoming data on a U.S. ICBM attack and informed his superiors, who would have likely pursued nuclear retaliation. Conversely, humans could underrely on systems out of a sense of doubt and assume the data provided by the system are incorrect or flawed when they are in fact correct.

Incentivizing Arms Racing

The arms race of new and emerging technologies is arguably already underway, with the potential to ramp up even further. "My real concern about arms racing right now is not a hypersonic arms race per se," said Jill Hruby, current administrator of the U.S. National Nuclear Security Administration and former head of a U.S. national laboratory that supports nuclear weapons development, in 2021. "But it's the arms race when all these technologies are kind of being developed at the same time, and we need to think through the possible interconnectivity that could be produced and what could be a pretty serious arms race if we're not careful."[29]

An arms race refers to the different rates of progress in the development and deployment among countries incentivizing each country to quickly pursue and deploy new, cutting-edge capabilities of its own so as to lock in a strategic stability advantage. Arms racing can take place in terms of quantity, meaning the number of particular weapons systems, and quality, referring to the ability of a system or an operation to be effective at accomplishing a certain mission.

A mixture of quantitative and qualitative factors has fueled the U.S.-Chinese-Russian race for new hypersonic boost-glide vehicles and cruise missiles. Washington has vocally expressed its intention not to fall behind Beijing or Moscow in its hypersonic weapons capabilities in numbers or quality.[30] "We're not as advanced as the Chinese or the Russians in terms of hypersonic programs," said Gen. David Thompson, the vice chief of U.S. space operations, in 2021. The United States has some "catching up to do very quickly."[31] Heidi Shyu, undersecretary of defense for research and engineering, emphasized in 2022 that "while strategic competitors are pursuing and rapidly fielding advanced hypersonic missiles, the [Pentagon] will develop leap-ahead and cost-effective technologies for our air, land, and sea operational forces."[32]

The space arms race also incorporates quantitative and qualitative aspects, with ASAT weapons capabilities standing out as the most likely to fuel the race, according to one survey.[33] The use of kinetic or co-orbital destructive ASAT weapons capabilities could damage target satellites and increase the amount of space debris in orbit, threatening all types of crucial space-based systems. Since 1968, a total of 16 known ASAT weapons tests by four countries have created an estimated 4,400 pieces of debris that remain in orbit and threaten spacecraft.[34]

An actor's perceptions, whether true or false, of another's capabilities could significantly speed up arms racing, as seen in the cyberspace and AI realms. "For example, there is no way for a country to verify the quality and scope of AI or computing mechanisms that another country is using to augment its system, and thus policymakers and strategists must rely on perception. Because of this ambiguity, a country's failure to send clear signals to its adversary could incentivize technology buildup and heighten arms-racing instability."[35]

Chapter 3

An Arms Control Tool Kit for New and Emerging Technologies

This report presents a tool kit of several potential arms control and risk reduction measures designed to mitigate the risks to strategic stability posed by new and emerging technological capabilities in the military sphere. The workshops proved instrumental in developing the tool kit.

The tool kit divides the measures into two categories: near and long term (Table 3.1). Near-term measures include those described as low-hanging fruit by workshop participants and achievable now or within the next five years. Long-term measures include those more ambitious and time consuming to achieve, putting the timeline more in the range of the next 10 years or beyond.

More than one measure in any category and across categories can and should be taken. Furthermore, risk reduction and arms control efforts should focus on pursuing multiple measures across domains and technologies that, taken altogether, create an effective, feasible, and sustainable arms control regime.

Each category aims to mitigate at least a few of the risks to strategic stability outlined in the previous chapter. In other words, the below risk reduction and arms control measures intend to

- slow down the pace of warfare so as to ensure sufficient time for decision-makers,
- enhance transparency of new and emerging technological capabilities between actors and intentions behind their use so as to guard against misperceptions and arms racing,
- identify and address potential new vulnerabilities exposed and the effects caused by the technologies to prevent worst-case scenario assumptions,
- strike the balance between involving as many actors as possible to ensure that any potential regulation is inclusive and comprehensive and refraining from overloading efforts with too many voices, and
- bolster the human role in the operational and decision-making loop to prevent a flash war between machines.

Near-Term Measures

Crisis communications systems. The need for functional, robust, and resilient crisis communications systems, also called hotlines, repeatedly emerged as a top priority for all the technologies in the workshops. These systems help dissipate the fog of war by allowing for communication between adversaries to facilitate confidential conversations between political or military officials, including heads of state, during crisis or war and to issue notifications before military maneuvers in areas where both operate.

The United States and the Soviet Union established a hotline just months after the 1962 Cuban missile crisis because the crisis illuminated the importance of dialogue between competitors, perhaps even especially so. More recently, Washington and Moscow set up a direct military-to-military hotline, or specifically in this context a deconfliction line, to avoid accidental military clashes in Syria.[36] The other side on the line, however, must answer in order to make hotlines an effective tool, an issue that is more political in nature.

Definition establishment. New and emerging technologies bring with them new systems, behaviors, and risks but not necessarily the shared language necessary to define and describe it all. Therefore, a tiny yet important initial step toward arms control for a new or emerging technology could be the establishment of shared or common definitions of key terms recognized by the world's majority. After all, as seen over the course of U.S.-Russian nuclear arms control, one word ("warhead") or phrase ("strategic stability") could hold different meanings between actors and affect the negotiation and implementation of arms control and risk reduction measures.

Table 3.1 - Arms Control for New and Emerging Technologies

Time Frame	Mechanism	Definition	Example
Near Term achievable now or within next five years	**Crisis Communications Systems**	General and specialized hotlines for political or military officials of adversaries to use during peacetime and especially in a crisis	Review and enhance existing cyber hotlines, or create new ones, among among China, Russia, and the United States so they prove functional, robust, reliable, and resilient
	Definition Establishment	Shared or common definitions of key terms recognized by the world's majority	Establish a language of strong, clear, and shared definitions for AI-enabled and autonomous weapons capabilities, accounting for uncertain future applications of the technologies to weapons systems
	Norms	Shared standards of responsible behavior of a capability in a specific domain (e.g., basic principles, best practices, guidelines, rules of the road, or codes of conduct)	Establish a requirement for meaningful human interaction with and control of autonomous weapons systems, an agreement on general accountability rules and methods for these systems, or an agreement on standards for their use or quality control
	Unilateral Declarations and Actions	Non-legally binding steps taken by a country without similar concessions required of another country and agreed to outside of a legally binding treaty	Commit to not conducting destructive direct-ascent anti-satellite missile testing in space, as seen by the eight countries who have already done so
	Confidence-Building Measures	Non-legally binding joint declarations or actions	Conduct a direct U.S.-Russian military-to-military exchange of information that identifies nuclear, non-nuclear, and dual-capable hypersonic weapons systems or that details the acquisition and deployment schedules of these systems
Long Term achievable in next 10 years and beyond	**Risk Reduction**	Informal voluntary actions, joint statements, or agreements, likely non-legally binding	Negotiate and implement an agreement for the space domain that codifies and expands existing norms of behavior and details standards for allowed spacecraft, as well as establishes a mechanism for regular consultation among parties
	Arms Control	An official form of mutual agreement or commitment, likely legally binding	Adjust the central limits of a future U.S.-Russian arms control arrangement to directly cover conventional and nuclear intercontinental-range, ground-launched, boost-glide missiles, such as Russia's Avangard, and to include a stronger "new kinds of strategic offensive arms" provision

The space domain, for instance, lacks strong, clear, shared definitions. The 1967 Outer Space Treaty deliberately did not have specific definitions. Therefore, China, Russia, and the United States could discuss and establish agreed definitions of behaviors for military systems and various activities in space, especially with respect to interactions between military satellites.[37]

The process of establishing definitions in the AI realm tends to be hampered by the nebulous nature of AI-enabled capabilities, the wide-range of AI military applications, and bureaucracy at the Convention on Certain Conventional Weapons (CCW). A solid technical definition of LAWS has also proven elusive because AI and autonomy could inhabit nearly any current or future weapons system with unpredictable results, upending any agreed definition.[38] Although challenging, the task of finding shared definitions could nevertheless prove useful because a technology and its functions should be understood before it could be subject to effective arms control. The discussion on definitions could and should take place in formal and informal settings, bilateral and multilateral talks, and Track 1, 1.5, and 2 dialogues (Box 3.1).

Norms. Shared definitions help provide the foundation needed to discuss and establish norms that describe responsible behavior of a capability in a specific domain. Other versions of norms include basic principles, best practices, guidelines, rules of the road, and codes of conduct. Both formal negotiation forums, such as official treaty negotiations or a UN committee, and more informal crisis communication channels could pursue and benefit from norms.

During the workshops, norms skeptics emerged time and again, doubtful that actors would genuinely uphold established norms, especially during times of conflict. Yet, participants acknowledged the benefits of norms, such as more formally instituting common understandings of systems, capabilities, domains, and behaviors and identifying when an actor behaves irresponsibly.

The space domain does not currently have shared norms of behavior for conducting military activities, such as noncooperative rendezvous and proximity operations, specifically nonconsensual close approaches of other satellites. China, Russia, and the United States could lead dialogue on such norms, perhaps in bilateral strategic stability dialogues or within the P5 process among the five nuclear-armed states recognized by the 1968 nuclear Nonproliferation Treaty. Norm building for space could also be undertaken in the UN Committee on the Peaceful Uses of Outer Space and the UN open-ended working group on reducing space threats, created in late 2021. The United States "believes that the most practicable, near-term solutions to enhance space stability and security include developing national security space-related norms of responsible behavior," emphasized Mallory Stewart, assistant secretary of state for the bureau of arms control, verification, and compliance, in February 2023.[39]

Box 3.1 - Multitrack Diplomacy

Track 1	Dialogue among government officials
Track 1.5	Dialogue between government officials and nongovernmental
Track 2	Dialogue among nongovernment individuals

Government officials includes those in political, diplomatic, military, or intelligence positions, while nongovernmental individuals include those in the nonprofit, academic, policy, research, and commercial/private sector circles.

As for AI and autonomy, potential norms on a unilateral basis, at the international level, or within the research community could focus on establishing a requirement for meaningful human interaction with and control of LAWS, an agreement on general accountability rules and methods for these systems, or an agreement on standards for their use or quality control.

The UN group of governmental experts (GGE) on LAWS within the CCW could take on efforts to establish such norms. The group agreed in 2019 on 11 guiding principles focused more on international humanitarian law and ethical concerns, but has not had much output since then.[40]

The United States has endeavored to establish a set of guidelines for AI-enabled weapons capabilities for itself and the international community. The Pentagon published its responsible AI strategy, which outlined ethical AI guiding principles, in June 2022.[41] One analyst, however, believes those principles are "not sufficient for implementing responsible AI principles across everything from development to acquisition to operations."[42]

In February 2023, the United States released "a series of non-legally binding guidelines describing best practices for responsible use of AI in a defense context," with the hope that other states will co-sign.[43] Described as "a proactive step," it has clauses calling for human control over nuclear weapons use.[44] Although not fully adequate on their own, guidelines can generate consensus among actors and help lay the foundation for more arms control and risk reduction measures.[45]

Unilateral declarations and actions. Unilateral declarations and actions are steps taken by a country to enhance stability and to offer transparency without similar concessions required of another country. A country tends to issue a unilateral declaration with the hope that the declaration would have a cascading effect, meaning that other countries would follow suit. In time, the declaration might gather enough support to transition into a confidence-building measure involving more parties or to be incorporated by an official agreement or treaty.

This type of effect has occurred in the space domain. The United States announced in April 2022 a unilateral commitment not to conduct destructive direct-ascent ASAT missile testing.[46] Over the following months, seven additional countries (Canada, France, Germany, Japan, New Zealand, South Korea, and the United Kingdom) also committed to the ban.[47] More countries, particularly those that have conducted destructive ASAT weapons testing or are developing ASAT weapons capabilities, could also commit to the ban.

In December 2022, the United Nations approved a U.S.-led resolution calling on all countries to commit not to conduct ASAT weapons tests, with more than 150 countries in favor.[48] Although largely a symbolic move, this step could create momentum for further space arms control.[49]

The cyberspace domain could also benefit from unilateral declarations and actions, specifically those intended to untangle conventional-nuclear integration. As conventional and nuclear systems become increasingly entangled, especially over the course of modernization programs, those systems also become more complex, which translates to an increased number of system components vulnerable to adversary infiltration.[50]

As one measure, the United States could declare its intention to run legacy and modernized NC3 systems simultaneously until the modernized system has a strong, proven track record of doing what the legacy system would do in the same scenario. This would help ensure the safety and security of the modernized NC3 system against cyberoperations. As an alternative, Washington could build its own essential core functionality system dedicated solely to supporting basic retaliatory NC3 functions.[51]

In 2022, the United States declared its plan to “commission an independent review of the safety, security, and reliability of U.S. nuclear weapons, NC3, and integrated tactical warning/attack assessment

U.S. Vice President Kamala Harris, second from right, on the day she announced the U.S. ban on conducting destructive direct-ascent anti-satellite missile testing, at Vandenberg Space Force Base in California in April 2022.
(U.S. Space Force photo by Tech. Sgt. Luke Kitterman)

The U.S. Air Force staffs missile silos with officers ready to launch nuclear weapons in case of an attack on the United States. (Photo by Jim Sugar/Getty Images)

systems," a review for which cyber experts have long advocated.[52] This review will aim to identify how the United States could strengthen safeguards "against the unauthorized, inadvertent, or mistaken use of a nuclear weapon, including through false warning of an attack."[53] Other nuclear-armed states, such as China or Russia, should consider conducting similar fail-safe reviews.

A subset of effective but more remote measures includes those that would adjust a country's nuclear declaratory policy or strategy. The elimination of a country's launch-on-warning option would allow more time to assess the nature of an incoming attack and the adversary weapons capabilities in use and to verify that information before decision-makers choose a response. The United States could also consider reconfiguring its nuclear forces to decrease the number of or to eliminate entirely its nuclear-armed, silo-based ICBMs, which stand ready to launch at any given time.

Unilateral measures can also aim to mitigate risks early in a system's life cycle. All states could establish new or updated test, evaluation, verification, and validation methodologies and practices to account for AI-enabled weapons systems, which some states have done already for conventional weapons. This measure could receive the backing of multiple nuclear-armed countries. After all, China, Russia, and the United States would want to operate some AI-enabled systems, such as early-warning systems, successfully regardless of the owner or the exact scenario because a false positive could lead to disastrous consequences.

Confidence-building measures. Confidence-building measures are joint actions or declarations, not formal treaties, intended to reduce the dangers or the risks of particular weapons capabilities or systems, promote transparency and minimize misperceptions, and foster a more conducive environment for a potential future binding agreement. These measures depend heavily on political willingness.

Data or information exchanges could serve as very useful confidence-building measures by pulling back the curtain on some uncertainties related to new and emerging technologies. The exchanges could look like a direct U.S.-Russian military-to-military exchange of information that clearly and correctly identifies nuclear, non-nuclear, and dual-capable hypersonic weapons systems or that details the acquisition and deployment schedules of these systems.

For AI, U.S., Russian, and Chinese scientists and technical researchers within and outside government could create a dialogue in which to discuss and exchange information on AI safety and standards; AI-enabled capabilities that may be incorporated into NC3; AI foundation models, i.e., AI models trained on vast troves of data and adaptable to a range of domains; and AI interpretability and controllability.[54]

The P5 process could also dedicate time for each nuclear-armed country to outline its respective general strategy on AI. Documents including information on these strategies, similar to the U.S. Department of Defense's directive on guidelines for the development and use of autonomous and semiautonomous systems, first published in 2012 and updated in 2023, could be publicly shared if not already.[55] Russia, for instance, could communicate the clear and concrete parameters under which the "Dead Hand" autonomous nuclear weapons control system would order a launch while not disclosing any confidential information.

To help facilitate data exchanges, China could establish a nuclear risk reduction center and connect it to the already existing U.S. and Russian centers. These centers would prove useful for a variety of confidence-building measures across numerous types of capabilities, systems, and domains.

As for cyberspace, the United States and Russia or the United States and China should consider a bilateral agreement to refrain from conducting cyberattacks on each other's NC3 systems. At the very least, the nuclear-armed countries can exchange information on their respective schedules and broad plans for cyber military exercises and the procedures for external observation and consultations concerning the exercises.[56]

Mutual military demonstrations of certain weapons systems of concern, such as hypersonic weapons, could also foster transparency and prevent misperceptions. China, Russia, and the United States could exchange observers at military exercises involving precision-guided missiles, such as hypersonic boost-glide vehicles or hypersonic cruise missiles.[57]

Long-Term Measures

The category of long-term measures includes those achievable within the next 10 years or beyond. The measures in this category include arms control and risk reduction arrangements (e.g., treaties, agreements) that involve more than one country and are more formal than confidence-building measures, although not necessarily legally binding. This category also includes new arrangements and revised existing or past arrangements.

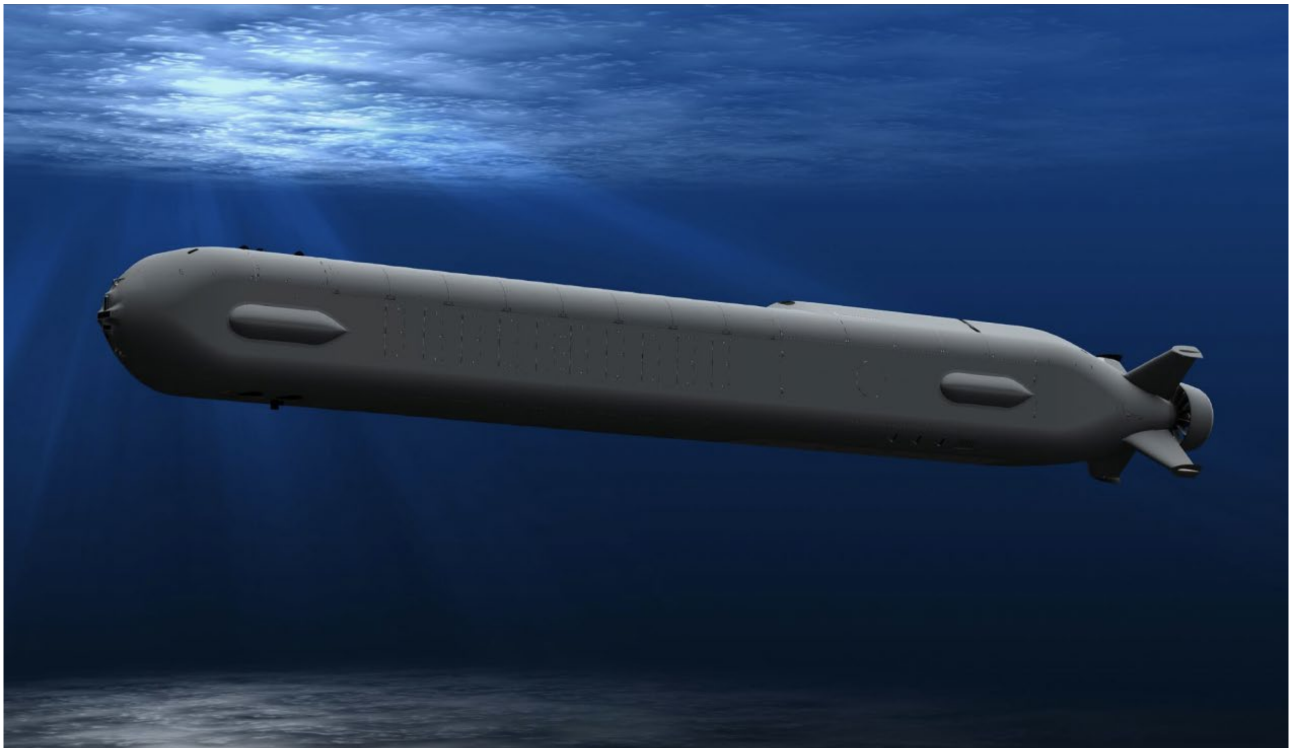
The 1987 Missile Technology Control Regime (MTCR), the 1996 Wassenaar Arrangement, and the 2002 Hague Code of Conduct Against Ballistic Missile Proliferation (HCOC) often emerge as possible measures to revise and expand in order to bring drones and LAWS within their purview, given their respective membership and stabilizing effects. There are 35 participating countries in the MTCR, 42 in the Wassenaar Arrangement, and 143 in the HCOC.[58] Although voluntary, these three arrangements provide a measure of transparency through data and information exchanges, foster communication among numerous states, and contribute to building shared norms.

The Wassenaar Arrangement focuses on conventional arms and dual-use technologies with control lists including lasers, computers, telecommunications, radar systems, stealth technology, and jet engine technology. The lists have undergone updates over the years, such as in 2015 to address intelligence sensors, an update that may be applicable to ISR drones. Meanwhile, the MTCR control list focuses on missiles and uncrewed delivery systems for nuclear, chemical, and biological attacks, with the HCOC further supplementing efforts to limit ballistic missiles.

Depending on the technology components of a weapons system, experts suggest that the control list of the Wassenaar Arrangement or the MTCR could be adapted in some instances to capture new and emerging technological capabilities. For the HCOC, arms control efforts could implement changes to its broad set of principles and recommended confidence-building measures. This type of approach toward arms control, however, comes with its own challenges, such as the fortification of an alienating in-group/out-group dynamic and the absence of an effective enforcement mechanism.

Alternative measures in this category include the creation of new arms control and risk reduction

A Russian Forpost uncrewed aerial vehicle taking off at Kubinka Air Force Base in Russia. (Photo by Artyom Anikeev via Getty Images)



An artist's rendering of the Extra Large Uncrewed Undersea Vehicle intended for the U.S. Navy. (Source: U.S. Navy)

measures, both entirely novel arrangements and those modeled on already existing arrangements. In 1972, the United States and the Soviet Union signed the Agreement on the Prevention of Incidents On and Over the High Seas. This agreement, struck after several incidents in the late 1960s, aimed to improve mutual understanding of military activities by decreasing the chances for an incident at sea and by providing the tools, such as crisis communications, to prevent such an incident from escalation if it did occur.[59] A similar document for the space domain, which is supported conceptually by numerous experts, could codify and expand existing norms of behavior and detail standards for allowed spacecraft, as well as establish a mechanism for regular consultation among parties.

Strategic nuclear arms control has swept up certain hypersonic weapons systems, although future arms control arrangements should more directly do so. A U.S.-Russian arrangement to succeed the New Strategic Arms Reduction Treaty could contain central limits that cover conventional and nuclear intercontinental-range, ground-launched, boost-glide missiles, such as Russia's Avangard system, as well as a stronger "new kinds of strategic offensive arms" provision that captures any nuclear and non-nuclear weapons of strategic range that enter the field after the treaty's entry into force.

The central limits of a new U.S.-Russian arrangement could apply to some AI-enabled and autonomous systems, such as Russia's nuclear-armed Poseidon torpedo. The capture of Poseidon under an arms control arrangement, however, could result more from the nuclear warheads on the system rather than the system's AI components. This has sparked an ongoing important debate among experts on whether arms control of systems similar to Poseidon should regulate its AI-enabled components or count the number of systems as deployed strategic warheads.

The increasing costs and the massive amounts of debris caused by collisions in space could prompt action on space arms control measures because all types of actors have a strong interest in protecting their space assets and associated terrestrial infrastructure. The most promising route for space arms control is the transition of the non-legally binding destructive ASAT weapons test ban into a legally binding multilateral treaty. As more countries commit to the ban, the pressure could grow for those on the sidelines to commit until a treaty formalizing the ban is not so far out of reach.

A major hurdle to such a treaty stems from the differing goals of space arms control: the goal of stability and security related to the militarization of space and the goal of environmental protection related to the congestion of the space domain and the creation of debris. The United States and its allies have supported the latter. Meanwhile, China and Russia have focused on the former, introducing multiple drafts of the Treaty on the Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects over the years at the United Nations, to no avail.

Signs of progress have nonetheless surfaced within the past few years, in addition to the moratorium on destructive ASAT weapons tests. The United Nations created the Open-Ended Working Group on Reducing Space Threats in December 2021, tasking it with developing recommendations on potential norms, rules, and principles of responsible behavior for the space domain, as well as on potential ways to contribute to the negotiation of legally binding agreements, including on the treaty proposed by China and Russia.[60] The group's findings are slated for release in the fall of 2023 during the 78th session of the UN General Assembly.

Although existing arms control arrangements could limit AI-enabled and autonomous weapons systems, at least initially, a de novo regime with tighter denial rules and a crafted membership might also be possible. As a potential starting point for drones, workshop participants suggested crafting rules that detail observable characteristics of aerial and underwater drones, especially those that threaten the survival of a country's second-strike nuclear capabilities, and describe activities to avoid, such as flying over silo-based or road-mobile ICBMs or traveling underwater near the possible location of nuclear-armed submarines in real time.

For autonomous systems, France has proposed within the LAWS GGE a two-tiered arms control approach: implementation of a full ban on LAWS that operate entirely outside of human control and regulation of other weapons systems that feature autonomy. This approach must work in parallel with ongoing research by experts on the intersection of LAWS and international humanitarian law, where legal questions of accountability and compliance emerge.[61]

Verification, although strongly preferred, is not always included in risk reduction and arms control arrangements due to technical and political challenges. Verification in the space domain, for instance, would need to capture not only space-based capabilities but also terrestrial-based counterspace capabilities. In addition, neither space situational awareness nor space traffic management can accurately identify, analyze, or characterize certain behaviors, even though they are useful for tracking spacecraft and collecting data.

Yet, risk reduction or arms control measures not paired with verification still could prove effective at bolstering strategic stability by minimizing the possibility for miscalculation and escalation. Plus, some of the new and emerging technologies, AI in particular, could provide new tools for verification.

Conclusions

The new and emerging technological capabilities with military applications examined in this report—hypersonic weapons systems, direct offensive cyberoperations, offensive counterspace capabilities, AI-enabled capabilities, drones, and LAWS—divide technical and policy experts, government officials, and political leaders over the potential effects of the capabilities on a conflict or confrontation. The potential range of their stabilizing benefits or their battlefield advantages is very real, but so are the potential risks that their use could contribute to moving a nuclear-armed country toward nuclear weapons use. After all, these capabilities could result in less time to make decisions, greater uncertainty as to what damage a capability may inflict or an attack's intention, a lesser role for humans to control a scenario or to act as firebreaks, and more incentives not to fall behind in new cutting-edge military capabilities.

Already in rather dire straits, existing nuclear arms control and risk reduction efforts aimed at preventing nuclear weapons use by accident or design become all the more complex and difficult to manage as new technologies, new actors, and new vulnerabilities emerge. These efforts, while challenging, provide concrete benefits for national and international security in peacetime and especially in times of conflict.

Each technology stands at a different stage in its respective research, development, testing, and potential deployment schedule, which will influence what particular arms control and risk reduction measures could and should be applied to a technological capability. Some capabilities, such as hypersonic weapons systems, largely rely on existing language and have already fallen into dialogue on future formal U.S.-Russian nuclear arms control arrangements. Other capabilities, such as autonomous weapons systems and counterspace capabilities, find themselves still in need of continued work on establishing definitions and norms of responsible behavior, which could provide a foundation for more durable, enforceable formal arms control arrangements in the future.

The political willingness of any given actor will certainly affect what particular measures are undertaken at what opportune times, but just as technologies develop, so do politics change. This tool kit is ready to be called on at any time, and the sooner the better. The task in the years ahead is to design a new security architecture that takes into account the rapidly approaching challenges and the risks of new and emerging military technological capabilities and pushes the prospect of nuclear war farther out of the realm of possibility.

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The Arms Control Association (ACA), founded in 1971, is a national nonpartisan membership organization dedicated to promoting public understanding of and support for effective arms control policies. Through its public education and media programs and its magazine, *Arms Control Today*, ACA provides policymakers, the press, and the interested public with authoritative information, analysis, and commentary on arms control proposals, negotiations, and agreements, and related national security issues. In addition to the regular press briefings ACA holds on major arms control developments, ACA staff provides commentary and analysis on a broad spectrum of issues for journalists and scholars in the United States and abroad.

The new and emerging technological capabilities with military applications examined in this report—hypersonic weapons systems, direct offensive cyberoperations, offensive counterspace capabilities, artificial intelligence-enabled capabilities, drones, and lethal autonomous weapons systems—divide technical and policy experts, government officials, and political leaders over the potential effects of the capabilities on a conflict or confrontation.

The potential range of their stabilizing benefits or their battlefield advantages is very real, but so are the potential risks that their use could contribute to moving a nuclear-armed country toward nuclear weapons use.

This report studies the potential destabilizing risks posed by the technologies and proposes both near- and long-term arms control and risk reduction measures to foster transparency, predictability, and strategic stability and to push the prospect of nuclear war farther out of the realm of possibility.

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