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XU TIANRAN AND MELISSA HANHAM

The Next 50 Years of Missile Proliferation

Since World War II, missile technologies have evolved at a rapid rate, and this trend is widely expected to continue. Whereas Nazi Germany's V-2 ballistic missiles were able to carry a one-ton warhead over a range of 320 kilometers, the Soviet Union was able to improve those capabilities in just 15 years for the R-7 intercontinental ballistic missile to 5.5 tons over 8,000 km. By the end of 1966, in a test, China had detonated a 12-kiloton live nuclear warhead on a medium-range DF-2A missile that was vastly superior to the German V-2 (China Academy of Engineering Physics 2014). Today, nuclear-capable missile technology is advancing and proliferating just as fast, if not faster.

More state and nonstate actors than ever before have built, bought, or stolen missile technology, and they will continue to do so in the coming decades. Furthermore, as new technologies increase the lethality, accuracy, reach, and survivability of existing systems, established military powers and new actors alike will strive to acquire them, potentially upsetting the status quo. Additionally, technologies such as computer modeling and additive manufacturing will accelerate the speed and decrease the cost at which new missiles can be tested, produced, and deployed.

This essay examines proliferation trends of nuclear-capable missiles over the past five decades and emerging technologies in order to project how missiles might proliferate in the future. The authors explore how nuclear-capable missile proliferation transpired in the last 50 years and its implications for the next 50 years of proliferation using the story of the Scud. They then examine existing technology and how it is proliferating to new states and nonstate actors. Next, they examine emerging missile technology, which may change a state's strategic calculations. They conclude by examining the ways in which current trends affect the adoption of future missile technology and its impact on nuclear proliferation.

SCUD:THE MOST PROLIFERATED MISSILE OF ALL

In the past 50 years, the Soviet ballistic missile R-17/Scud has become one of the most popular ballistic missiles around the world because it has a relatively simple design and is easy to reproduce. It or its derivatives have proliferated to a number of countries such as Egypt, Iran, Iraq, Libya, Myanmar, North Korea, Nigeria, Pakistan, Peru, Syria, the United Arab Emirates, Yemen, and Vietnam (NTI 2015). Even some non-state actors possess this nuclear-capable, short-range ballistic missile.

Countries such as North Korea and Iran have reverse-engineered the original design and made significant improvements. For example, they replaced the steel body skin with a lighter aluminum alloy and replaced the original inertial guidance system with a more compact one. In North Korea's case, the airframe has been widened and lengthened to store more propellant. The North Korean extended-range Scud is estimated to be able to deliver a warhead of 500 kilograms to a distance of about 1,000 km (Schiller and Schmucker 2016), while the Qiam, Iran's modernized Scud, has a 645 kg warhead and a maximum range of 800 km, according to Iranian state media (Press TV 2018). Iran has proliferated the Qiam missile to the Houthi in Yemen and Syria. The Islamic State used these missiles to attack the US Ain al-Asad air base in Iraq in January 2020 with surprising accuracy (Roblin 2020). Although Iran does not possess nuclear warheads for its missiles, it could in the future.

A much more capable ballistic missile utilizing Scud technology that may continue to proliferate is North Korea's Hwasong-7/Rodong. The Hwasong-7 engine has a design that is very similar to that of the R-17/SCUD's engine, but it is bigger and offers about twice the thrust. As a result, the Hwasong-7/ Rodong missile's performance almost doubled that of the Scud. After obtaining the original Scud from Egypt, North Korea scaled up the Scud and passed on the Hwasong-7 designs to Pakistan and Iran in the 1990s (Bermudez 1999).

As of now, only three countries are users or manufacturers of the Hwasong-7-origin missiles: North Korea, Iran, and Pakistan. North Korea and Iran have been improving the missile in the past decades. Iran's Ghadr, a domestic Hwasong-7 variant, has an estimated range of close to 2,000 km (Missile Defense Project 2020), which is achieved primarily by increasing the propellant volume and reducing payload mass. North Korea merely adopted a compact guidance set but did not lengthen the Hwasong-7/Rodong's airframe. It is likely North Korea can mount a nuclear device on it. Pakistan's Ghauri version of the Hwasong-7 is currently in service with the Pakistan Army's Strategic Forces Command and is capable of carrying a nuclear warhead (Inter Services Public Relations Pakistan 2018).

By clustering four Hwasong-7 engines, North Korea and Iran have built powerful first-stage engines for their space launch vehicles. Even assuming Hwasong-7 technologies will not proliferate further, if similar engine-clustering is adopted, Scud-possessing countries with enough of an industrial base could in theory be able to build a midrange ballistic missile with performance close to that of the Soviet R-12. Alternatively, Iran and North Korea could choose to proliferate their systems as they did with the original reverse-engineered Scud.

It is also worth noting that despite the use of a lightweight aluminum alloy airframe, North Korea and Iran have displayed an ability to fuel the Scud and Hwasong-7 missiles in a horizontal position before transporting them to launchpads. The more common practice is to erect the empty missile first and then fuel it immediately before launch in order to reduce the risk of damage and accidents during transportation. Thus, fueling liquid-fuel missiles before moving them out of their shelter could significantly reduce the amount of time for the missile systems to stay in the open. This makes them less vulnerable to surveillance and attack from adversaries and therefore more survivable.

The Scud is a perfect example of how a simple and reliable missile became the missile of choice for developing nations. If the international arms control community fails to take effective action, Scud will continue to proliferate to still more actors. Such a wave would be particularly concerning because these missiles have already been improved with lighter alloy airframes, improved guidance, and better survivability. They have also been clustered to form stages of dual-use space launch vehicles — that is, vehicles having military as well as civilian applications. This makes them an ongoing proliferation threat, particularly as the technology to develop them becomes cheaper and easier.

EXISTING MISSILE TECHNOLOGY AND IMPACT ON STATE AND NONSTATE ACTORS

In the next several decades, missile technologies currently limited to major military powers will proliferate broadly to state and nonstate actors. This will complicate the international security environment and lead to more complex proliferation networks.

Higher Performance Liquid-Fuel Missiles

North Korea and Saudi Arabia, like the long-standing military powers, possess a number of higher energy liquid-fuel missiles, namely North Korea's Hwasong-12/14/15 and the Chinese DF-3. Missiles with higher-energy liquid fuel can carry the same payload further or a heavier payload the same distance, making them an attractive step for states seeking nuclear weapons. North Korea is an excellent example of how missile capabilities became a useful indicator of future nuclear capabilities. Other countries can follow Pyongyang's path. September 2016 marked the public debut of North Korea's 80-ton thrust engine linked to its Hwasong-12 intermediate- and Hwasong-14/15 intercontinental-range ballistic missiles. This new powerful engine uses a more energetic fuel, allowing North Korea to have intermediate-range and intercontinental ballistic missiles for the first time.

The US Department of the Treasury identified Iranian individuals involved with the North Korean development of an "80 ton engine," which is likely the same one that Pyongyang displayed in 2016 (US Department of the Treasury 2016). This current relationship between Iran and North Korea can be taken as an example of what future relationships between proliferating states might look like. This engine may have been collaboratively designed, though there is little evidence in the open-source literature to support such a theory.

Saudi Arabia is now the only user of the Chinese DF-3 missile, which is powered by a cluster of four YF-1 engines. Each YF-1 has thrust that is comparable to that of the Hwasong-7/Rodong, but it is more efficient with fuel. The challenge of making higher-performance liquid-fuel engines lies in overcoming difficulties presented by higher combustion temperature and chamber pressure, associated issues with cooling, and manufacturing of higher-energy propellant. Nevertheless, Scud-possessing countries with a sufficient industrial base may try to develop more-efficient engines in the coming years. If such highly efficient engines were to be proliferated, the ability of Scud-possessing countries to launch long-range attacks would be boosted significantly.

Solid-Fuel Ballistic Missiles

Compared with liquid-fuel engines, solid-fuel rocket motors are more economical and easier to handle once a state has cleared the hurdle of carefully designing and safely testing the motors. Under proper storage conditions, solid-fuel missiles can be stored for a long time with minimal requirements for maintenance, meaning they can circulate on road-mobile vehicles and be launched rapidly. Thus, solid-fuel missiles have become the primary means of delivery for the five nuclear weapon states recognized by the Nuclear Nonproliferation Treaty (China, France, Russia, the United Kingdom, and the United States) and now the other nuclear-possessing states (India, Israel, North Korea, and Pakistan) are following.

Pakistan, North Korea, and Iran have developed large, staged solid-fuel ballistic rockets. The North

Korean Pukguksong missiles have a diameter around 1.5 meters and can be launched from land-based platforms and submarines. Iran's Sejjil missile is about 1.25 meters wide and is longer than the North Korean Pukguksong. The development status of these missiles remains uncertain.

Several Chinese entities have been put under sanctions for alleged missile technology transfers since 1991 (Wisconsin Project on Nuclear Arms Control 2008). In a recent incident, Indian authorities detained a Chinese ship on its way to Karachi, Pakistan, on February 3, 2020, for allegedly declaring a false end-use for an industrial autoclave that, according to Indian authorities, can also be used in the manufacture of ballistic missiles (Gupta 2020). Separately, scholar Jeffrey Lewis claimed in 2014 that China, with the quiet approval of Washington, secretly sold DF-21 solid-fuel midrange missiles to Saudi Arabia in 2007 (Stein 2014).

Recent commercial developers of space launchers have introduced creative solutions to simplify the design of solid-fuel rockets.

Apart from obvious tactical advantages mentioned above, solid-fuel rocket motors have a simpler structure and far fewer parts than liquid-fuel engines. But developing and producing high-performance solid-fuel motors is challenging. Iran experienced a devastating explosion at al-Ghadir missile base at Bid Ganeh in 2011, though it is not known if this was due to accident or sabotage. Similarly, Iran experienced a suspicious explosion at the Shahid Bakeri Industrial Group, which makes solid-propellant rockets for the Khojir missile facility east of Tehran (Gambrell 2020). Regardless, both Iran and North Korea have moved ahead with robust testing of solid-fuel motors, making them potential new leaders in proliferation (Lewis and Schmerler 2018).[1]

The Soviet two-stage, solid-fuel ballistic missile Temp-S/9K76, which entered service in 1967, can deliver a warhead of some 500 kg over a 900 km range (Kirill 2016). As mentioned above, the same performance can be achieved by a Scud variant, which is about the same size as the Temp-S but has only one stage. Manufacturing large-diameter motors also requires mixing stations, casting stations, insulation, and machining facilities that are more sophisticated than the production line of smaller solid-fuel rockets. In addition, it is more complicated to reliably and accurately terminate thrust (to cut the power in time to achieve accuracy) of solid-fuel motors. Controlling attitude in pitch, yaw, and roll for a solid-fuel rocket is more challenging than for a liquid-fuel engine. However, recent commercial developers of space launchers have introduced creative solutions to simplify the design of solid-fuel rockets. For example, the Chinese KZ-1A has a liquid upper stage (Integrated Propulsion and Attitude Control System) that controls the attitude of the first three solid-fuel motor stages by lateral jet and fine-tunes the trajectory for accurate orbital insertion so that each solid stage spares its own thrust termination system and attitude control unit (except the first stage, whose aerodynamic control surfaces will take over lateral jet when the rocket reaches a certain speed). Another Chinese four-stage solid-fuel rocket, the Smart Dragon-1, uses a combination of aerodynamic control surfaces on the first stage and a lateral jet control system located in the nose cone and around the fourth-stage nozzle to control the attitude of all four solid-fuel stages with fixed nozzles (Gao and Gu 2019).

Such trends in the rapidly growing space launch service industry might encourage some countries with a weaker industrial base to pursue long-range solid-fuel ballistic missiles despite previous hurdles. Still more difficult from a regulatory perspective is the fact that space commerce will contribute to a quantitatively and qualitatively more difficult dual-use trade to control.

1. Iran's new site is at Shahrud, where the solid-fuel storage facilities can be seen with thick dirt berms to guard against future explosions. The motors are tested horizontally inside a nearby giant crater (Fisher 2018). North Korea is expanding an already large facility near Hamhung, where it similarly has built berms around storage facilities and tested motors at horizontal test stands nearby (Lewis and Schmerler 2018).

From a purely developmental point of view, more states will acquire the ability to produce larger solid-fuel motors with a width of more than one meter in the coming 50 years. Through staging technologies, capabilities for medium, intermediate, and even intercontinental range can be achieved. Export controls on dual-use civilian and commercial items are already weak, and as these technologies rapidly evolve, the law will likely continue to limp behind.

Subsonic Cruise Missiles

Subsonic cruise missiles are like mini-planes, as they rely on wings for lift and an air-breathing engine to produce thrust. They can stealthily penetrate an air defense network by flying below the radar line of sight and path planning. Some have a range of over 2,000 km. Some of these cruise missiles are also capable of carrying nuclear weapons. Inertial guidance units and satellite positioning systems are becoming more accessible to all state and nonstate players. As a result, nuclear-weapon states no longer have a monopoly on subsonic cruise missiles. Modern manufacturing methods such as 3D printing have helped to simplify the production process for turbojet or turbofan engines and lower their cost. For example, Taiwan's National Chung-Shan Institute of Science and Technology has developed a 3D-printed cruise missile engine that can be manufactured in army workshops in 40 to 50 hours (Hong 2019).

India, Iran, Pakistan, South Korea, and Taiwan have developed and deployed their own subsonic cruise missile systems. The 2019 attack on the Saudi oil facilities at Abqaiq and Khurais, while not nuclear, proved that rudimentary cruise missiles and drones manufactured by a country with a relatively weak industrial base can exhibit dangerous capabilities when it comes to avoiding detection (Brumfiel 2019).

With the increased availability of satellite positioning providers and novel production methods, production costs will drop and the effectiveness of the delivery system will increase. As a result, new countries and even nonstate actors will likely invest in land attack cruise missiles.

New Actors Interested in Existing Technologies

Interest in pursuing missile capabilities is closely associated with the strategic intentions and threat environment of state and nonstate players. Generally speaking, those that are more likely to engage in armed conflict are more willing to pursue better capabilities as offensive and deterrent measures.

Regional tension in the Middle East, Eastern Europe, South Asia, Northeast Asia, the East China Sea and the South China Sea could continue to encourage a number of states and territories – for example, China, Japan, Malaysia, North Korea, the Philippines, South Korea, Taiwan, and Vietnam – to develop the means to conduct missile strikes. It is not difficult to envision scenarios in which missiles might be used: a possible armed conflict across the Taiwan Strait could spiral into a full-blown war; there is no clear sign of mitigation or resolution for multiple conflicts in the Middle East; the possibilities of armed conflict between Russia and neighboring countries such as Ukraine will continue. Thus, it is likely that countries and territories will invest in some of the existing technologies mentioned above to enhance their missile strike abilities. Still more worrisome is that technologies such as the Scud, already deemed a poor state's weapon, can increasingly migrate to substate groups in Southeast Asia, Eastern Europe, the Middle East, South Asia, Africa, and Latin America through proliferation.

EMERGING MISSILE TECHNOLOGY TRENDS

The proliferation of existing missile technologies to states and nonstate groups will pose new security challenges, but missile technologies will also evolve. The United States, Russia, China, and some regional powers will continue to invest in emerging technologies as they seek to continue to boost their capability to penetrate enemy defense systems.

Loitering Munitions

Recent regional conflicts have witnessed the use of so-called loitering munitions, which can remain in the air for a period of time, allowing the operator to look for and choose targets. The basic concept of the loitering munition is to put a warhead on an unmanned aerial vehicle, also known as a drone, that is flown into a target. These drones have the characteristics of both subsonic cruise missiles and surveillance drones. This kind of hybrid is called a "cruise drone missile" (巡飞弹) in China (CCTV 2020). Thus, some modern cruise missiles, including the nuclear-capable ones, can also perform the role of loitering munitions.

Currently, most loitering munitions are small drones powered by rotary engines or electric motors. Most of them are easy to build and have a small payload. Due to their simplicity, there is little doubt that the loitering munitions will continue to proliferate into the hands of state and nonstate actors. Their designs will focus on further reducing radar and infrared signature, increasing the ability to plan an autonomous flight path, and further cutting costs. It is also possible that heavier, nuclear-capable loitering munitions will be developed in the future.

Modern supersonic cruise missiles were first used as anti-ship missiles, but their role has expanded to land attack.

Supersonic Cruise Missiles

Supersonic land-attack cruise missiles are becoming more prevalent. These supersonic weapons are mostly powered by a ramjet engine, which enables them to reach a maximum speed of about Mach 3.

Unlike typical subsonic cruise missiles, which rely on wings and relatively dense atmosphere to provide lift, the ramjet-powered high-speed missile is best suited to fly at high altitudes to reduce aerodynamic drag and increase range. Yet there are costs to pursuing this capability. A ground-based missile defense network could see the rapidly approaching targets from afar. Compared to subsonic missiles, the heat signature of supersonic cruise missiles is also much more obvious to infrared sensors of air defense systems. On the other hand, the time to initiate an interception of such a fast-flying target is shorter. A supersonic cruise missile capable of agile maneuver could make the interception even more challenging.

Modern supersonic cruise missiles were first used as anti-ship missiles, but their role has expanded to land attack. The French nuclear-armed air-launched cruise missiles ASMP and ASMPA, which entered service in 1987 and 2009, respectively, are among the earliest dedicated land-attack supersonic cruise missiles. In French nuclear doctrine, these are "pre-strategic" weapons serving as the last "warning shot" before the full-scale use of strategic nuclear weapons (*Bulletin of the Atomic Scientists* 1990).

Taiwan is reportedly pursuing such weapons. Its Yun Feng cruise missile is said to be based on the Hsiung Feng-III supersonic anti-ship missile and has a range of around 1,500 km. According to local media, production of the first batch of 20 missiles was approved in 2018 (Zhu 2018). Other systems include the Russian Bastion-P and the Indian Brahmos missiles. Their land-attack versions are also based on the original anti-ship versions.

China officially unveiled its massive DF-100 supersonic land attack cruise missile in its 2019 military parade. This missile may also have an anti-ship variant. Countries are increasingly likely to put nuclear payloads on such systems; doing so will deeply affect strategic calculations of the future.

Hypersonic Weapons

A hypersonic weapon is an aerial vehicle that travels at speed of Mach 5 or above and can perform maneuvers during flight. Hypersonic weapons are even faster than supersonic cruise missiles. Yet it is a common misunderstanding that they necessarily travel faster than ballistic missiles. The term "hypersonic" is used mainly to describe missiles that are capable of high-speed evasive maneuvers in flight, which complicates the task of missile interceptors deployed against them.

Major nuclear powers, such as China, Russia, and the United States are investing in hypersonic weapons. Russia declared its Vanguard strategic hypersonic glide vehicle (HGV), which is placed on top of existing silo-based liquid-fuel intercontinental ballistic missiles (ICBMs), to have entered active duty in December 2019. China has deployed its DF-17 midrange ballistic missile, which adopts an HGV as its payload. It is reported that the Vanguard is an unpowered HGV, while the Russian Navy's Tsirkon missile is a hypersonic cruise missile that is powered by a scramjet (supersonic combustion ramjet). The missile reportedly travels at a top speed of Mach 9 with a range of about 1,000 km. It is reported that 10 more tests will be conducted in 2020-2021 before Tsirkon is to be delivered to the Russian Navy (TASS 2020). The United States is currently developing multiple hypersonic missiles with a variety of capabilities and missions, including through the Navy, the Air Force, the Army, and the Defense Advanced Research Projects Agency (Sayler 2020). While the United States argues that its hypersonic missiles are not intended to be nuclear-capable, there is little to convince adversaries that they will not be.

As some delivery systems can carry both conventional and nuclear payloads, states that are under attack will be faced with the increasing problem of determining which delivery devices are carrying conventional payloads and which are carrying nuclear warheads.

This issue of discrimination is a problem not only for hypersonic missiles, but for all new delivery systems. As some delivery systems can carry both conventional and nuclear payloads, states that are under attack will be faced with the increasing problem of determining which delivery devices are carrying conventional payloads and which are carrying nuclear warheads. These calculations, which must be made in a matter of a few minutes, may push risk calculations to err on the side of an aggressive offensive response.

Today only a handful of countries are capable of developing long-range hypersonic weapons that can deliver a nuclear payload. In the coming decades, however, it is possible that more players, even countries with weak aerospace industries, will enter this field. North Korea has tested the KN-23 and KN-24 short-range ballistic missiles multiple times. Both are boost-glide weapons with a quasi-ballistic trajectory and can maneuver in flight. Such technologies and relevant experiences can be very helpful for the development of longer-range HGV weapons.

Nuclear-Powered Cruise Missiles

In response to missile defense systems, Russia is developing the nuclear-powered, nuclear-armed 9M730 cruise missile. Little is known about this missile, but the cruise missile can theoretically penetrate missile defenses by taking advantage of its purported "unlimited range" (BBC 2019) like a never-resting loitering munition. This is not a new idea or technology. The United States studied such concepts and gave them up in 1964. Russia's test failure in August 2019 demonstrates that it can also result in environmental catastrophe in case of an accident of its nuclear engine. It remains doubtful that other state or non-state actors will develop similar weapons (Axe 2019).

CHALLENGES TO CURBING PROLIFERATION

Today's emerging technologies will improve the range, payload, accuracy, and survivability of missiles. In addition, missile design, testing, and production will be faster, cheaper, and easier. High-performance computers and modeling software make development of new designs easier and reduce testing. It has become theoretically possible for every state or nonstate actor with access to a reasonable education system and industrial base to pursue missile technologies that were available only to well established military powers in the last 50 years.

The adoption of composite materials and novel manufacturing technologies such as more-advanced additive manufacturing capabilities offer faster and cheaper ways to make lighter airframes. Design information is also moving to digital formats, creating new challenges in combating espionage, smuggling and export control violations.

Today, even some start-up companies are able to build very capable solid- or liquid-fuel space launch vehicles that can easily be converted into intermediate-range or intercontinental ballistic missiles. Some commercial liquid-fuel launchers use liquid oxygen as the oxidizer. This increases the handling requirements and limits combat readiness because these rockets need to be fueled immediately before launch. However, the majority of first-generation ballistic missiles, such as the German V-2, Soviet R-5, Chinese DF-2A, and US Redstone, used liquid oxygen as the oxidizer. Liquid oxygen could be ideal for emerging actors that want to keep open the option of military uses, as it not only offers higher efficiency but also helps promote the civilian-use-only image of their projects.

Meanwhile, more and more commercial-use receivers for satellite positioning systems and off-the-shelf commercial inertial guidance components can be put to military use, making the missiles more accurate. Would-be missile possessors these days rarely smuggle missiles in whole. To avoid customs inspections, they ship small parts that are hard to identify, raw materials, commercial machine tools, and goods whose military applications are not easily recognizable to customs officials and licensing organizations due to the volume of legitimate trade or a lack of knowledge on emerging technologies.

Export Controls

Today represents a powerful moment for missile proliferation. The commercial space industry is moving into territory that previously belonged only to states. Additive manufacturing is moving many states' most secret knowledge into a digital format, which, if stolen, is very easy to transport across a border. Laws and norms have traditionally lagged behind scientific and technological achievements. This is particularly true in missile proliferation, where the dual-use nature of aerospace technology has put considerable pressure on export controls.

Unfortunately, the entity charged with checking missile-related exports, the Missile Technology Control Regime (MTCR), is not well positioned to do the work that needs to be done. It is a voluntary group of 35 states that does not include China, Pakistan, North Korea, or many of the countries that, due to their location, may offer launch services for space commerce in the next 50 years. The regime has been working hard to update the list of items in its Equipment, Software and Technology Annex to move away from completed delivery systems and toward components, a shift that is in line with the way missile proliferation has changed in the last 30 years. However, it is a never-ending task for which successes will become more and more difficult as the definition of "basic scientific research" will evolve rapidly in the next 50 years and the items that the regime seeks to control become more intangible (MTCR 2019).[2]

Impact on Nuclear Proliferation

Missile technology and nuclear weapon technology are distinct in their specific scientific details but linked in their policy impact. In the past 50 years, all states that have produced nuclear weapons also have produced the missiles to deliver them. Today, commercial launch services are available in the United States, Russia, China, and elsewhere. It is likely that rocket manufacturing, like other manufacturing sectors, will move to territories with the most favorable commercial terms. Thus, while dual-use rocket technology is likely to see rapid growth, it will not be tied to a state or nonstate actor's desire to produce a nuclear weapon.

Missile proliferation may have an impact on how existing nuclear possessors choose to deploy their nuclear weapons and signal their intent. States with more powerful missiles can afford to have a simpler, heavier warhead. At the same time, nuclear proliferation will likely have a strong effect on missiles. As nuclear warheads are designed to be more compact or have more powerful yields or both, states will seek missiles that are more survivable, accurate, and capable of overcoming missile defense systems. Since the Cold War, states have been researching advanced missile technology to serve these three purposes, and they are likely to continue to do so. North Korea is an example: measurements of the Hwasong-15 ICBM show space for multiple independent reentry vehicles

2. According to the MTCR, "basic scientific research" means "experimental or theoretical work undertaken principally to acquire new knowledge of the fundamental principles of phenomena and observable facts, not primarily directed towards a specific practical aim or objective."

(MIRVs). North Korea has yet to demonstrate MIRVs, but with such a vehicle, researchers will be watching for them (Hanham 2019).

States will increasingly face discrimination problems as missile technology improves and nonstate actors continue to acquire more-advanced missiles. States will need not only to determine who is launching the missile, but also to quickly establish if the missile is carrying a nuclear warhead. Still more cumbersome is what happens when a nonstate actor launches what will likely be a conventional missile from a state that has nuclear weapons. With missile technology development unchecked, we will begin to enter a time in which nonstate actors in Pakistan, or perhaps someday Iran, could spoof a nuclear weapon launch, simply because they have similar capabilities in conventional missiles. Conversely, nuclear weapon possessors may even see an advantage in attributing an attack to a nonstate actor to divert blame.

To prepare for the coming trends, the MTCR should include China, Pakistan, and other emerging missile powers.

CONCLUSIONS

Missile proliferation history indicates that state and nonstate players will pursue missile technologies either as offensive or defensive measures based on their own perception of threats. The main goal for states will be keeping their missiles survivable and capable of overcoming missile defenses.

Simple and reliable missile technologies are also the most popular choices for non-state actors. For those future malicious actors seeking to cause a nuclear exchange, there may be a desire for advanced missiles that cause a discrimination dilemma. The combination of emerging technologies with actors that have the desire to pursue missile capabilities as a result of heightened regional tensions is likely to prompt further development and proliferation of missiles and more widespread use of them in future conflicts. The lack of proactive and cooperative risk reduction measures could result in an intentional or accidental initiation of an exchange of missiles, possibly carrying nuclear weapons.

To prepare for the coming trends, the MTCR should include China, Pakistan, and other emerging missile powers. Trade with missile proliferators and nonstate missile possessors should be rigorously controlled to curb further proliferation of missile technologies. The states in question should establish and strengthen their national export control regimes, comply with international regulations on export of dual-use technologies, and educate their universities and companies about risks of export violations. However, while strict control regimes might be able to slow down proliferation to a certain degree, they cannot stop proliferation in the long run, given the continuing process of global industrialization and increasingly open access to technologies.

Policymakers must prepare for a world with more uncertainty and more risk. For example, a clear line needs to be drawn between conventional and nuclear-armed missiles to reduce the risk of nuclear exchanges resulting from misinterpretation of intentions during a conventional armed conflict. Under such circumstances, ensuring that decision-makers have access to high-quality information that enables them to make the best decisions in the face of escalating conflict is the key to avoiding armed conflict and even a nuclear exchange in response to error, uncertainty, or misdirection. ■

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BIOGRAPHIES

XU TIANRAN is an Analyst for Open Nuclear Network (ONN), a programme of One Earth Future. He is an expert on open source analysis and military technology. Mr. Xu focuses on North East Asian security and offensive and defensive missile systems. Tianran uses photo mensuration to measure the size, range and capacity of missiles. He also analyzes photos, videos and satellite imagery to understand nuclear and missile programmes.

With a background in media and journalism, Tianran is a regular contributor to Chinese and English open source and science publications. Prior to joining ONN, he worked as a journalist, editor and news assistant at both Chinese and foreign news organizations for 10 years in Beijing. He graduated from Xi'an International Studies University, China. Tianran is fluent in Chinese, English and German.

MELISSA HANHAM is an expert on open-source intelligence, incorporating satellite imagery and other remote sensing data, large data sets, social media, 3D modeling and GIS mapping. She is particularly focused on the monitoring and verification of international arms control agreements using open-source evidence. Melissa also uses open-source information to study export-control systems and proliferation finance activities. She is an affiliate of Stanford University's Center for International Security and Cooperation and a board member at BASIC. In 2018, Ms. Hanham was awarded the Paul Olum Grant Fund for being one of the most inventive scientific and technical minds working to reduce the threat of nuclear weapons.