Russia's War in Ukraine: Ballistic and Cruise Trajectories

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Cover

Exhibition of destroyed Russian missiles shot down over Ukraine on August 23, 2023 in Kyiv, Ukraine. (Andriy Zhyhaylo/Obozrevatel/Global Images Ukraine via Getty Images)

Executive Summary

Russia's war on Ukraine has been calamitous for its land forces, and an unnecessary tragedy for Ukraine's people. It has also provided a further proving ground for a variety of 'ballistic' and cruise missile types, at once illustrating the utility and sometimes the limitations of such classes of weaponry. The war has for the first time seen the limited use of an air-launched aero-ballistic missile and the large-scale operation of direct attack munitions, or one-way uninhabited aerial vehicles. Cooperation on the latter is drawing Moscow and Tehran closer together, with uncomfortable implications for many countries concerned as to the destabilising behaviour of the two states.

Moscow's war will almost certainly further fuel the demand for long-range conventionally armed land-attack cruise missiles and pique greater interest in direct attack munitions among state and non-state actors. This is at a time when the arms control architecture for managing ballistic and cruise missile acquisition has already been greatly eroded. The remaining mechanisms for managing the spread of such systems have never been more ill-suited for the task.

Irrespective of the abject failure of Russia's initial campaign aims, and its now more often sporadic use of land-attack cruise missiles, there is no indication there is any lessening of interest in such systems. Rather, states that already have similar systems, alongside nations that are looking to acquire such capabilities, may draw conclusions that support the development of more capable land-attack cruise missiles, with greater numbers to be held in inventories. Moscow's use of the Iranian *Shahed*-136 (*Geran*-2) direct attack munition, furthermore, will almost certainly encourage others to seek similar weapons, either as an entry-point for a long-range land-attack capability, or as an adjunct to an existing cruise missile inventory.

Alongside the lesson of 'quantity having a quality of its own', the comparative success of Ukrainian ground-based air defence in engaging Russian cruise missiles, even if the claims are considerably exaggerated, will propel interest in greater survivability. Options include greater numbers, greater stealth, and greater speed, alongside supplementing cruise missiles with lower-cost higher-volume decoys or direct attack munitions to try to overcome ground-based air defence. Moscow may well redouble its own efforts to develop high-supersonic or hypersonic (Mach 5+) cruise missiles for the land attack role. In turn this may encourage other states to follow suite, or to try to access Russian technology or systems. Tehran has already claimed it is pursuing supersonic missile technology, and Moscow could offer a path to expediting this.

The development of long-range single role-weapons, be it for land-attack against fixed targets or for the anti-ship mission will be replaced increasingly by multi-role weapons capable of being used to engage a broad target set. This poses an additional challenge not only to the defender, but also for any arms control architecture that will need to capture such multi-role weapons. Besides turning to Tehran, Moscow has used some of long-range surface-to-air missile inventory in a secondary surface-to-surface role to supplement its own short-range ballistic missiles (SRBM). It also re-introduced into service an SRBM it had withdrawn, again to bolster its inventory.

Managing emerging demands and technology developments in the long-range precision land-attack realm was a demanding enough task prior to Russia's full-blown invasion of Ukraine. It is a task now made doubly more difficult by Moscow's naked aggression.

Introduction

Russia's use of ballistic and cruise missiles as well as direct-attack munitions in its full-scale invasion of Ukraine has not just shed light on the effectiveness and limitations of those systems. It also has highlighted the tactics Moscow chooses to employ, and the relationships it is willing to utilise to maintain a steady influx of equipment.

Some lessons from the war are already apparent. While Russia has not prosecuted many key Ukrainian military targets sufficiently to achieve its desired objectives, from a technical perspective, short-range ballistic missiles (SRBMs) have performed relatively successfully against land targets and ground-based air defences. Subsonic land-attack cruise missiles (LACMs) have had a patchier record. The use of ageing anti-ship missile designs in the land-attack role has also highlighted their lack of accuracy.

As Ukraine's Western-supplied ground-based air defence has become increasingly capable, Russia has turned to the large-scale use of low-cost direct-attack munitions to overwhelm those defences and improve the survivability of more costly systems. However, the mixed record of subsonic LACMs may mean that Russia will further invest in the development of high-supersonic or Mach 5-plus LACMs into its inventory alongside slower and cheaper cruise missiles and direct-attack munitions.

The ramifications of Russia's use of ballistic and cruise missiles in Ukraine extend beyond the current conflict. Russia's war has reinforced pre-existing trends in the development and acquisition of precision-strike munitions, which have proved detrimental to the already-eroded global framework for controlling the spread of certain types of missile technology. The conflict has demonstrated the military utility of certain types of missiles and direct-attack munitions, some of which may become cheaper to produce as designers rapidly innovate using battlefield lessons. Against the backdrop of growing geopolitical tensions and some state and non-state actors' demand for such systems, greater licit and illicit procurement and domestic production of these weapons is likely.

This paper considers the types of ballistic and cruise missiles Russia and Ukraine have used in the conflict, the tactics they have employed and why these have, and have not, been successful. It also considers the lessons that Russia is drawing from its experience in Ukraine for its future missile force development, as well as the future proliferation trends of certain types of systems. The paper is divided into five sections. The first describes the evolution of Moscow's thinking on precision-strike systems and the role of such systems as described in Russian military doctrine. The second and third sections discuss Russia's (and to a more limited extent, Ukraine's) employment of cruise and ground-launched ballistic missiles in its war on Ukraine and Western equipment transfers. Lastly, we conclude with an assessment of the implications of the use of these missiles in Ukraine on procurement trends and non-proliferation policy.

1. History and Doctrine of Russian Use of Precision-Strikes

Russia's interest in long-range precision-strike systems is rooted in the Soviet Union's 'revolution in military affairs' thinking of the 1970s and 1980s, when Moscow started considering a conventional war option after a period of sole reliance on nuclear deterrence.[1] Early Soviet writings on long-range precision-strike focused on the concept of a 'reconnaissance-strike complex' (*razvedyvatel'no-udarnnyy kompleks)*, combining the use of precision munitions, wide-area surveillance and automated command and control (C2).[2] Strategists postulated that the potential destructive power of precise conventional weapons could make them as useful as nuclear weapons to destroy certain key targets.[3]

The United States' development of precision weapons and their successful employment in *Operations Desert Storm* in 1990-1991 and the Kosovo War in 1999 provided further impetus for Moscow to introduce analogous capabilities.[4] Moscow pursued the development of what Russia calls 'high-precision weapons' (*vysokotochnoye oruzhiye*) throughout the tumultuous 1990s and into the 2000s. Russia's struggling economy caused delays in development and production that drove the introduction of stopgap designs such as the air-launched Kh-555 (RS-AS-22 *Kluge*) cruise missile until more advanced designs, such as the stealthier air-launched Raduga Kh-101 (RS-AS-23a *Kodiak*) land-attack cruise missile entered production.[5] Russia has also introduced into service a new short-range ballistic missile (SRBM), an air-launched ballistic missile (ALBM) and multiple types of air-, ground- and sea-launched cruise missiles (ALCM, GLCM and SLCM, respectively).[6] Technological advances in guidance and precision systems were crucial to building a viable conventional strike capability.

In the 2000s, Russia's military thinking on the role of high-precision weapons to reinforce its strategic deterrent continued in parallel with research and development efforts. As a result, the development of these systems was incorporated into Moscow's 2008 'New Look' military reforms, a sweeping effort to revitalize the armed forces after the poor performance in Russia's short war with Georgia at that time.[7] Conventional precision-strike subsequently became embedded in Russian doctrine. The term 'non-nuclear deterrence' (*pred'iadernoe sderzhivaniya*) first appeared in Russia's 2014 Military Doctrine.[8] It assigned 'high-precision weapons' a similar role to nuclear weapons in threatening to inflict unacceptable damage on an adversary to deter them or drive them to de-escalate from conflict on terms favourable to Moscow.

Russia devised its strategy recognizing it lacked sufficient conventional precision-strike capabilities to credibly threaten NATO's analogous capabilities. Russian strategists, therefore, advocated that in a conflict, their armed forces should limit strikes on vital NATO military targets to demonstrate resolve and generate symbolic or political impact.[9] If limited strikes were unsuccessful, targeting could be scaled up to inflict varying levels of damage on an opponent to terminate a conflict on terms favourable to Russia.[10] In such a scenario, Russian military thinking calls for destroying critically important economic, political and military infrastructure with conventional and possibly nuclear weapons. Russia's 2020 nuclear doctrine outlines scenarios in which Russia could use nuclear weapons, with an emphasis on when the 'existence of the state' is threatened, but it is left deliberately vague

Russian President Vladimir Putin chairs a Security Council meeting at the Kremlin in Moscow on 26 December 2014, where he signed into law the country's new military doctrine

(Alexei Druzhinin/RIA Novosti/AFP via Getty Images)

as to what such a threat may look like.[11] While some analysts have argued that a growing role of conventional precision-strike in Russia's military operations makes nuclear weapons use by Moscow less likely, others say that Russia's integration of conventional and nuclear weapons means that Moscow views the distinction between nuclear and conventional weapons as insignificant, and that Russia could therefore use nuclear weapons early in a conflict with minimal consequences.[12]

2. Cruise Missile Use in the Russo-Ukrainian War

Land-attack cruise missiles (LACMs) are now a ubiquitous element of modern warfare, and Russia's war of aggression against Ukraine is proving to be no different. Russia has employed LACMs launched by air, maritime, and land forces in attacks on Ukraine.[13] What is less certain is the efficacy of these cruise missile attacks in the face of credible, if thinly spread, ground-based air defences. The effectiveness of Russia's LACMs use also may have suffered from poor mission planning and execution, limited inventory depth and a lack of variety of tactical systems to employ. Russian targets have included fixed Ukrainian military installations and critical national infrastructure but given the

The *Storm Shadow*/SCALP EG LACM is almost certainly the longest-range weapon that Western states have so far provided to Ukraine

(Ben Stansall/AFP via Getty Images)

Western Transfer of Stand-off Weapons

A decade ago, the notion of integrating a European-designed land-attack cruise missile (LACM) on a Soviet-era combat aircraft would have seemed outlandish, even more so the notion that it be used to attack Russian forces.

The United Kingdom embarked on such a task, likely toward the end of 2022, looking to integrate the MBDA *Storm Shadow* LACM on the Sukhoi Su-24M *Fencer* D ground-attack aircraft. In May 2023, the UK government said it had 'donated' *Storm Shadow* missiles to Ukraine to support Kyiv's effort to defend itself against Moscow's full-scale invasion. The provision of the *Storm Shadow* is almost certainly the longest-range weapon so far provided to Kyiv. The Su-24M's combat radius, combined with the range of the *Storm Shadow*, provides the Ukrainian Air Force with a notional strike range of more than 800 kilometres.

The UK has been one of the most forward-leaning Western countries providing weaponry to Ukraine, with the transfer of LACMs arguably the most notable example. Some other nations have been more hesitant to provide longer-range weaponry over concerns that this might be 'escalatory'. Germany, for instance, has struggled to decide whether to provide the MBDA *Taurus* KEPD 350, a weapon similar to the *Storm Shadow,* albeit with a longer range and more powerful warhead. France has followed the UK and provided Ukraine with its version of *Storm Shadow*, the SCALP EG.

In announcing the 'donation' on 11 May 2023, the then-secretary of state for defence Ben Wallace said the weapon would allow Ukraine to attack Russian forces 'within Ukrainian sovereign territory'. Ukraine has used domestically-developed uninhabited aerial vehicles to strike targets inside Russia but has only fired the *Storm Shadow* against targets within occupied Ukrainian territory. This constraint was likely one of the provisions of the transfer.

Integration of the *Storm Shadow* with the Su-24M posed several challenges. Those included developing a physical interface with a Soviet-era weapon pylon and finding a way to get a comparatively modern European air-launched cruise missile to interface with Soviet-era avionics.

The missile has extended Ukraine's ability to target Russian command and control and logistics sites. Moscow had relocated some of those further from the front line after the United States provided Kyiv with High Mobility Artillery Rocket Systems (HIMARS), which can launch precision strike rockets to ranges up to 80 km. *Storm Shadow* offers far greater range and has allowed Ukraine to target critical infrastructure, such as bridges connecting the Crimean Peninsula to Kherson. The missile's range also improves the survivability of the Su-24M, allowing weapon release outside of Russian medium- and long-range air-to-air and surface-to-air missile engagement zones.

The *Storm Shadow* experience in Ukraine reinforces the military utility of conventionally armed air launched LACMs. Countries looking to draw lessons from the war will likely consider whether, if they presently lack a weapon in this class, they need to field the capability either through domestic development or acquisition from a foreign supplier.

The Kh-101 is integrated on the Tupolev Tu-160 *Blackjack* (pictured) and the Tu-95MS *Bear* bomber aircraft

(Wojtek Laski via Getty Images)

numerous instances of cruise missiles striking residential dwellings across Ukraine, it is far from clear what the intended targets sometimes were.[14]

Transparency of the war is limited, with the belligerents issuing over-stated claims about the successes of their offensive or defensive capabilities. What is apparent is that neither has secured air supremacy or even air superiority for any length of time. Kyiv's claims of successful LACM intercepts are near certain exaggerated.[15] If this is not the case, it would likely be the first war involving the air domain where such figures were not inflated. But Ukraine's ground-based air defence is verifiably shooting down some number of the air-launched Raduga Kh-101 (RS-AS-23a *Kodiak)* and naval Novator 3M14 (RS-SS-N-30a *Sagaris*) cruise missiles.[16]

The roughly 18 months of fighting have raised multiple questions about the use of LACMs. One is how many Russian systems are falling to Ukrainian air defence rather than failing to reach their targets because of technical malfunctions.[17] Another is how Moscow is responding, both in the short- and medium-term, to rectify these issues. More broadly still, what, if any, are the wider implications of Russia's experience in Ukraine for its cruise missile development plans.

Speed and Mass

Since the outset of the war, Russia's Aerospace Forces has principally deployed the Kh-101 land-attack weapon from Tupolev Tu-95MS *Bear* mod and Tu-160 *Blackjack* mod bomber aircraft. Recently, LACMs use has become sporadic, with the number of missiles employed in any one attack often fewer than numbers seen in the initial wave of strikes in the first few weeks of the war. Ukraine has been able to engage at least some Kh-101s, even though the missile features low-observable design characteristics and onboard defensive aids.

Moscow could draw multiple lessons from this element of its air campaign. Those include that Russia had an insufficient inventory of LACMs at the outset of the war, not prosecuting key targets sufficiently and repeatedly in deviation from Russian military thinking, that subsonic LACMs face increasing challenges from ground-based air defence, and that this class of missiles benefits from being supplemented by high-volume lower-cost weapons with a complementary range performance of the very long-range cruise missiles to divert missile defences.

Development of the conventionally armed Kh-101 and its nuclear variant, the Kh-102 (RS-AS-23b *Kodiak)* began toward the end of the 1980s.[18] The Kh-102 was developed to replace the Raduga Kh-55 (RS-AS-15 *Kent*). The conventional variant may have entered production around 2010.[19] First used operationally in Syria in 2015, the Kh-101 appeared to perform relatively well.[20] This, however, was in a permissive air environment, where there was no credible ground-based air defence. Russia also encountered reliability issues in the early stages of the Syria operation.[21]

Despite Moscow displaying the capability to conduct precision-strikes on a limited scale, Russia's LACM performance in Syria may have been patchier than initially thought. Russian Defence Minister Sergei Shoygu noted that during the Syrian operation the Kh-101 targeting cycle was too time-consuming. He also said there were

Russian officials visit the Raduga missile manufacturer outside Moscow in February 2023. Raduga produces several LACM systems, including the Kh-101

(Yekaterina Shtukina/Sputnik/AFP via Getty Images)

other problems, without elaborating, except to indicate that those had been resolved.[22]

Moscow's intervention in Syria also saw the first operational use of the Raduga Kh-555 (RS-AS-22 *Kluge*).[23] This missile uses the Kh-55SM (RS-AS-15B) airframe with a conventional rather than nuclear warhead and features a modified guidance system to provide greater accuracy than the nuclear variant. The use of the heavier conventional warhead also drove some airframe changes. The Kh-555 was an interim capability developed as a stopgap until the Kh-101 was available. Despite repeated reports that the VVS has used this missile in Ukraine, no imagery has yet emerged to support this claim.[24] It is possible that Russia only converted a limited number of Kh-55s and expended most during operations in Syria.[25] Russia has also modified a limited number of Kh-55SM missiles by removing the nuclear warhead and replacing this with ballast, with the likely intention to use these as decoys to divert Ukrainian air defences.[26]

Russia has supplemented its more modern LACMs with the Raduga Kh-22 (RS-AS-4 *Kitchen*) and a limited number of the Raduga Kh-32 (RS-AS-4 mod 4), an upgraded version of the Kh-22.[27] Originally an anti-ship weapon, the Kh-22MA variant was designed for land attack. It is unclear which version, or versions, of the Kh-22 Russia has used in Ukraine. It also has employed, though in smaller numbers, the Kh-32. They all appear to lack the accuracy required for precision land attack. Despite its age, press reports suggest Ukrainian ground-based air defence has struggled to down the Kh-22.[28]

Similarly, Russia has also used its K-300P *Bastion* (RS-SSC-5 *Stooge*) coastal-defence cruise missile on occasion in a secondary land-attack mode. Its accuracy, or otherwise, in this role has yet to become clear, but it too has been reportedly difficult to engage successfully.[29]

The Kh-22/Kh-32 and the K-300P are all medium to high supersonic missiles, while some also fly low flight profiles. The high speed partly suggests why these weapons have been more difficult for Ukrainian air defences to engage than the subsonic Kh-101 or 3M14. Russia also on occasion has used another high-speed weapon, the 9-S-7760 *Kinzhal* (RS-AS-24a *Killjoy*), an air-launched version of the 9M723 (RS-SS-26 *Stone*) surface-to-surface short-range ballistic missile. Kyiv, perhaps curiously, has claimed more success in engaging successfully *Kinzhal*.[30]

Recent Russian military writing highlights interest in achieving yet greater missile speed, as illustrated by a March 2023 essay in the Defence Ministry's in-house purportedly academic journal Military Thought.[31] The paper, 'The Use of the Aerospace Forces Strike Aviation in Future Military Conflicts', notionally considers Moscow's future air-warfare needs, but also looks to identify shortcomings and draw lessons from the air campaign in Ukraine. The authors urge Moscow to expedite the acquisition of Mach 5-plus cruise missiles. Russia's air-launched weapons manufacturers have at least two publicly known high-speed cruise missiles in development. The Tactical Missile Corporation (KTRV) is working on a project associated with the names *Gremlin* and *Lichinka,* the generic designator Kh-MT and Kh-41.[32] KTRV's Zvezda-Strela is likely working on the Kh-41, while the Raduga branch is linked to the *Ostrota* project. The latter may deliver a ramjet-powered cruise missile for delivery by Russian Tu-22M3 *Backfire* and Su-34 *Fullback* aircraft.[33] Raduga is also working on the Kh-69, a shorter-range air-launched LACM likely akin to the European *Storm Shadow* or *Taurus* KEPD 350K missiles.[34] The Kh-69 is undergoing flight testing.[35]

One potential effect of the war in Ukraine is to reinforce Russia's goal of introducing Mach 5-plus LACMs into its inventory to improve weapon survivability against increasingly capable air defence. Whether this will result in a reduced emphasis within its inventory on subsonic LACMs over time remains unknown. But given the cost of developing and producing high-speed weapons, these

will likely continue to be supplemented by subsonic systems, at least in certain roles and target sets.

Russia appears to be addressing some of its missile survivability and inventory depth issues also at the lower end of the technology spectrum by introducing more direct attack munitions – sometimes called one-way uninhabited aerial vehicles – into service. Moscow acquired the *Shahed*-131 and *Shahed*-136 from Iran in the second or third quarter of 2022.[36] These have been used not only to engage targets but also to try to deplete Ukraine's inventory of ground-based air-defence interceptors. The *Shahed*-131 and *Shahed*-136 are known in Russian service as the *Geran*-1 and *Geran*-2 respectively. Russia is reportedly working toward manufacturing the *Geran* domestically.[37]

Remains of an Iranian-designed *Shahed*-136 UAV exhibited in Ukraine. Russia procured Iranian UAVs in the second or third quarter of 2022

(Oleksii Samsonov /Global Images Ukraine via Getty Images)

3. Ground-Launched Ballistic Missile Use in the Russo–Ukrainian War

Russia has used various types of ballistic missiles throughout its war against Ukraine. However, the Russian Ground Forces' only sporadic use of this capability at the war's outset was surprisingly unaligned with Russian military thought and was therefore unable to achieve the desired effect. While Russia's Ground Forces increased the pace of short-range ballistic missile launches once it became clear that the initial efforts were inadequate, that did not compensate for the earlier underperformance.[38] What drove Russia's inability to attack key Ukrainian targets sufficiently and frequently enough at the outset of the conflict were weaknesses in Russia's kill chain (especially of its intelligence, surveillance and reconnaissance [ISR] capabilities), its slow and formulaic targeting cycle, its limited reload capacity as well as Ukrainian active and passive countermeasures.

While this might suggest to some observers that conventionally armed ballistic missiles have limited military utility in modern warfare, Russia's use of short-range ballistic missiles (SRBMs) should instead provide states with a lesson on how *not* to use this capability. Ballistic missiles have been effectively used at scale by other countries in the post-Cold War era – most notably the United States' use of the MGM-140/168 Army Tactical Missile System (ATACMS) in 2003 – to achieve tactical effects. Military planners trying to draw lessons from Russia's ballistic missile use in the Ukraine conflict have to recognize the wrong as well as right lessons to better use and defend against this capability in the future.

Russia's Use of Ground-Launched Ballistic Missiles in Ukraine

The principal SRBM used by Russia's Ground Forces is the 9K720 *Iskander*-M (RS-SS-26 *Stone*) weapons complex. The missile, known by its GRAU index as 9M723, is a single-stage, solid-fuel, road-mobile ballistic missile that can carry a 480–700 kilogram warhead.[39] An 9M723 can be equipped with a variety of different warhead types depending on the target type (e.g., soft-skinned vehicles, hardened structures), including cluster munitions, unitary high explosive and nuclear payloads.

Most analysts estimate the missile has a range near the upper end of its roughly 350–600 km capability.[40] The 9M723 missile travels along an aero-ballistic trajectory below an altitude of 50 km and at speeds of up to Mach 7.[41] The missile can perform in-flight horizontal and vertical manoeuvres, providing it with some capability to evade ballistic missile defences. It is also equipped with up to six penetration aids to spoof missile defences.[42] The *Iskander*'s 9P78-1 transporter erector launcher (TEL) is capable of carrying two 9M723 missiles that can be launched within one minute of each other.

Iskander was designed to fill a capability gap that was created after the Soviet Union eliminated the 9K714 *Oka* (RS-SS-23 *Spider*) SRBM under the 1987 Intermediate-Range Nuclear Forces (INF) Treaty. Some Soviet and later Russian officials viewed the elimination of the *Oka* missile as a 'betrayal' by then Soviet premier Mikhail Gorbachev and welcomed the design work on *Iskander*.[43] With *Oka*'s unexpected early retirement removal from the Soviet arsenal, *Iskander* instead became a replacement for the Soviet-designed 9K79 *Tochka*-U (RS-SS-21 *Scarab* B) SRBM which began service with the Soviet Ground Forces in 1989.

The *Iskander* appears to have reached initial operational capability by 2008 when it was used in very small numbers by Russian Ground Forces during the Russian–Georgian War.[44] The missile appears to have reached full operational capability in 2011 when – according to the Russian Ministry of Defence – the 26th Missile Brigade in Luga, in the Leningrad Military District, became the first brigade of the Russian Army to receive its full complement of 12 launchers.[45] Modernising Russia's tactical missile forces was an essential part of Russia's 2011–2020 State Armaments Programme, the intention of which was to implement 'modernisation' across all branches of Russia's armed services.[46] By 2017, the Russian Ground Forces' then ten

Russia's 9K720 *Iskander*-M (RS-SS-26 Stone) short-range ballistic missile

(Sefa Karacan/Anadolu Agency via Getty Images)

tactical missile brigades appeared to have replaced their *Tochka* missiles with the *Iskander* SRBM.[47] The Russian Ground Forces activated three more *Iskander* brigades between 2017 and 2020.[48] The IISS estimates that Russia possesses roughly 150 *Iskander* launchers organised into 13 brigades, with a planned strength of 12 9K720 *Iskander*-M launchers per brigade.[49]

Russia used the *Iskander* complex for a second time in a conflict in its intervention in Syria, with an apparently small number of launchers deployed to Hmeimim airbase in Latakia in March 2016.[50] Details on the purpose and use of *Iskander* in Syria is limited, although Russia officials claim that they were 'effective'.[51] As with the Russian Aerospace Forces and Russian Navy's use of land-attack cruise missiles against Syrian opposition targets, Russia's intervention in Syria likely provided the Ground Forces with useful operational experience using *Iskander* in battlefield conditions.

In preparation for its 2022 invasion of Ukraine, Russia appears to have deployed at least three brigades to support its operations. At least one unit was deployed in Belarus.[52] At the outset of the war, 9M723 missiles were used to strike high-value Ukrainian targets from Belarus and Russia.[53] Russia's military doctrine calls for intensive use of precision fires against high-value military, political and economic targets within a short timeframe. However, data collected from Ukrainian and US defence sources suggest the actual employment strayed from that philosophy. Ukraine's National Security and Defense Council (NSDC), for instance, states that 124 9M723 missiles were used in a roughly five-month period between 24 February and 21 July 2022.[54] Although such data should be treated cautiously, the number of accumulated missile launches recorded by the NSDC broadly aligns with figures provided by the US Department of Defense, suggesting some credibility.[55]

The apparent limited use of the 7M23 missile suggests that, as with Russia's use of land-attack cruise missiles (LACMs), Moscow did not attack key Ukrainian targets with the intensity its own doctrine called for in the opening stages of the conflict. US intelligence assesses that Russia probably planned for a quick military victory.[56] This deficiency becomes apparent when comparing data of US SRBM launches during *Operation Iraqi Freedom* in 2003 against Russian missile launches in 2022. On the first day of US operations in Iraq, for example, a single US Army unit launched 102 ATACMS SRBMs against Iraqi targets, including corps and division command and control posts, air defences, artillery and ground forces.[57] US fire plans were typically organised with salvos of at least 20 missiles for each target. As a result of these launches, the opposing Iraqi division had 'ceased to exist as a coherent fighting force' within a single day.[58] Comparatively, towards the beginning of Russia's invasion, footage on social media shows that *Iskander* SRBMs were typically launched in salvos of 3–4 missiles for each fire plan, for an estimated total of 124 SRBM launches in a five-month period.[59] Within one-tenth of the time period, the US Army launched more than three times the number of SRBMs.[60]

Russia's relatively limited use of ballistic missiles, coupled with a seemingly restrained use of other precision-guided missiles – especially LACMs – left key Ukrainian command and control nodes, assembly points, storage and equipment sites largely unscathed

in the early phases of the conflict. Satellite imagery analysis of the Mirgorod airbase in Poltava *oblast*, for instance, shows that although Russia targeted the airfield within the first month of the war, the amount of destruction was limited to four craters along the runway and main apron and three destroyed unhardened aircraft shelters. Multiple other shelters, revetments and maintenance areas were apparently not successfully targeted, and several craters near the taxiway indicate misses. The limited amount of damage and apparent lack of subsequent successful targeting by Russian precision-strike capabilities has meant that the runway was subsequently repaired, allowing Ukrainian Air Force's Su-24 *Fencer* and Su-27 *Flanker* to continue operating from the airfield judging by the frequent repositioning and relocating of aircraft in subsequent months.[61] Similarly, satellite imagery analysis shows that Vasylkiv Air Base in Kyiv *Oblast* was targeted in the opening phases of the war, although the limited amount of damage has meant that the Ukrainian Air Force was able to initially disperse aircraft and then subsequently resumed operations from it. Other important military sites, such as command and control nodes, were also not attacked by Russia at the war's outset. Satellite imagery analysis of Ukraine's Ministry of Defence building, for instance, shows that it was apparently targeted in the first week of the war, with at least one missile landing in the building's interior courtyard. However, the lack of follow-up targeting is apparent, given the lack of damage to the building or the surrounding area. By comparison, the US aggressively and repeatedly targeted Iraqi command and control nodes from the beginning of its 2003 invasion.[62] Even if Russia did follow up with strikes on subsequent dates, it is likely by then that Ukrainian personnel would have since dispersed to more secure locations.

Russia appears to have increased its usage of 7M23 missiles once it became clear to Moscow that its invasion would not be a quick success. Data from the Ukrainian Ministry of Defence states that Russia had launched a total of 829 7M23 missiles by 18 November 2022, a three-fold increase in the average rate of missile launches per month from the February–April period.[63] This data should be treated cautiously, however, given that figures released by the Ukrainian Ministry of Defence are sometimes inconsistent and contradictory. Given the lack of evidence for subsequent Russian targeting of some important Ukrainian military facilities, it is likely that large numbers of these missiles were used to strike Ukrainian energy infrastructure and smaller military formations and equipment.

Russia's Utilisation of Old Systems

As well as the 9M723 ground-launched ballistic missile, the Russian Aerospace Forces have also employed on a few occasions the 9-S-7760 *Kinzhal* (RS-AS-24a *Killjoy*) air-launched ballistic missile (ALBM). *Kinzhal* is an air-launched version of the 9M723. Launching the missile from a MiG-31K *Foxhound* D aircraft at high altitude increases the missile's range which is assessed to be in excess of 2,000 km.[64] Like the 9M723, *Kinzhal* can manoeuvre to evade missile defences and can be equipped with a nuclear or conventional warhead.[65] Russia is estimated to have only a limited stockpile of *Kinzhals* following its entry into service in 2019, though the exact number is unknown. The Aerospace Forces possesses an estimated 24 MiG-31K aircraft launch platforms. Russia first used *Kinzhal* on 18 March 2022 against a Ukrainian underground ammunition storage facility in Delyatin, Ivano-Frankivsk Oblast.[66] While ALBMs present air defences with speed and trajectory challenges, Ukrainian forces have claimed to have intercepted *Kinzhal*-type missiles on several occasions using the US-designed MIM-104 *Patriot* surface-to-air missile.[67]

Russia has employed the 9-S-7760 *Kinzhal* (RS-AS-24a *Killjoy*) ALBM, seen here on a MiG-31K *Foxhound* D aircraft, in Ukraine on several occasions

(Sefa Karacan/Anadolu Agency via Getty Images)

As well as using its more modern types of ballistic missiles, Russia has also used older systems that it had retired within the last two decades as part of the armed forces modernisation directive. For instance, the *Tochka*-U was nominally retired by 2017, yet the Russian Ground Forces have taken some systems out of storage for use in Ukraine. Social media footage shows what are unmistakably several *Tochka* 9P129 TELs marked with 'V' identification emblems – a symbol Russian forces have displayed during the Ukraine war – arriving by rail into Melitopol on flatbeds in July 2022.[68] Other 'V'-marked *Tochka* 9P129 TELs have been recorded on railway flatbeds in Belarus and filmed in Luhansk.[69] Because of the weapon's guidance limitations, there is a risk that the missile may miss its intended target. One strike against an unknown target in Kramatorsk in August 2022 using two *Tochka*-U SRBMs, for instance, killed over 30 Ukrainian civilians at the city's train station.[70] Despite Russia's Ministry of Defence rejecting that it carried out the strike, evidence of two SRBM launches taking place from the Russian-occupied town of Shakhtars'k at the time of the attack suggests that it, or Russian-backed separatists, are very likely responsible.[71]

Despite the retirement of *Tochka* from the Russian Ground Forces system, it is likely that Russia still retains a large number of those missiles and launchers that are awaiting dismantlement. There are multiple overlapping reasons why Russia would choose to use the older *Tochka*, including reducing pressure on the available remaining inventory depth of more modern systems such as the 9M723, the availability of large numbers of *Tochka* missiles and launchers, the higher than expected number of Ukrainian targets beyond what capabilities are available to Russia's Ground Forces, attempting to offset the effectiveness of Ukrainian air and missile defences and, at a more basic level, using these weapons negates the need for dismantling them.

Ukraine's Use of Ballistic Missiles

While Russia has used SRBMs throughout the conflict, Ukraine's use of this type of weaponry has been more limited, likely reflecting the dearth of launchers and missiles available to the Ukrainian armed forces. To compensate for the shortage, Ukraine has requested SRBMs from its Western supporters, notably the US-designed ATACMS. Discussions between Kyiv and Washington on the transfer of ballistic missiles are ongoing, although the Biden administration has repeatedly rejected Ukrainian requests and voiced concerns that transferring SRBMs will escalate the war.[72]

Although Washington may eventually change its mind and supply Kyiv with this weapons type – as it has with several other types of equipment it had earlier signalled were off limits – the US continues to supply Ukraine with a large number of other precision-guided munitions that partially fill this capability gap, such as 227mm M30 rocket (more commonly known as the Guided Multiple Launch Rocket System or GLMRS). US defence planners are likely to have already determined the utility of ATACMS to Ukraine and how many might be able to transfer. More uncertain, however, is whether this could cause Russia to seek an external supplier for its own diminished ballistic and cruise missile stockpile.

Ukrainian SRBM Capabilities

The only SRBM currently available in the US's inventory is the ATACMS. The M57 variant of the missile is a single-stage, solid-fuel SRBM that has a maximum range of 300 km and is equipped with a 227 kg warhead.[73] The M57 can be equipped with a unitary or cluster warhead, depending on the target type.

Ukraine first requested ATACMS from the US around May 2022.[74] Other NATO members possessing the missile besides the US are Greece, Romania and Turkey.[75] Considering that a third-party transfer would require Washington's approval under the US's Arms Export Control Act, it is very unlikely that any of these countries will supply Ukraine with ATACMS.[76]

Kyiv has been eager to acquire ATACMS to augment the Ukrainian armed forces' limited (although growing) capability to conduct precision strikes against targets inside Russian-occupied territory and to make up for its diminished capability to launch surface-to-surface ballistic missiles due to inventory shortages. Before Russia's 2022 invasion, Ukraine was assessed to possess around 90 9K79 *Tochka*-U (RS-SS-21 *Scarab* B) launchers organised into one missile brigade.[77] The *Tochka*-U is a Soviet-designed single-stage, solid-fuel, road-mobile SRBM that has a maximum range of 120 km and is equipped with a 480 kg conventional warhead.[78] The missile has

An ATACMS missile being launched from the White Sands Missile Range, New Mexico, 1990. Kyiv has been eager to acquire ATACMS

(Corbis via Getty Images)

an estimated circular error probable (CEP) of roughly 95 metres.[79] Although Ukraine has successfully used its *Tochka* SRBMs against large Russian targets, including sinking the *Tapir*-class (*Alligator*) landing ship Saratov while it was docked in Berdyansk port in March 2022, the weapon's CEP means that it lacks the same level of accuracy of more modern SRBMs to strike small targets with a high level of certainty.[80] The *Tochka*'s 120 km-range also means that important Russian aerospace and naval sites in occupied Crimea are beyond the range of Ukrainian ballistic missiles (although Ukraine has used British/French supplied LACMs to successfully target these sites).[81] Compared with the *Tochka*-U, ATACMS is able to strike targets twice as distant and roughly nine times as accurately. It is also likely that Ukraine has diminished its stockpile of *Tochka* missiles, with limited options for replenishment as the missile's original design bureau, KB Mashinostroyeniya, is based in Russia. Ukraine may, however, have some indigenous capacity to produce new missiles.

To improve its self-sufficiency in ballistic missile production, Ukraine's KB Pivdenne design bureau began developing an indigenous SRBM known as *Grom*-2 in 2013. The missile has been described as analogous to Russia's 9K720 SRBM and was similarly planned to eventually replace Ukraine's *Tochka* arsenal.[82] Development work on the missile was purportedly halted for several years in the 2010s, but was recently restarted.[83] The Russian Ministry of Defence claims to have intercepted *Grom*-2 missiles on several occasions in 2023 however, it has not provided any evidence and it appears that the missile had not entered service.[84]

Western Hesitancy Regarding SRBM Deliveries to Ukraine

Western states have provided Ukraine with certain types of long-range guided weaponry, most notably LACMs, but have been reluctant to provide Kyiv with a SRBM. Washington has said transferring these systems to Kyiv might escalate the conflict, fearing a transfer would cross a red line for Moscow. The US also may be reluctant to diminish its own ATACMS inventory. The US Army is developing a follow-on weapon to replace ATACMS, the Precision Strike Missile (PrSM), but it will not be fielded until 2024.

US President Joe Biden has said that because SRBMs could be used to strike targets inside Russia, their transfer might escalate the war.[85] However, as ATACMS has a shorter range and a smaller payload than other stand-off weapons that some NATO members have donated to Ukraine, such as the British-French *Storm Shadow*/SCALP EG LACM, it is unclear why ATACMS's smaller range and payload are an impediment to US decision-making and why Russia would view this transfer with greater hostility. While Moscow expressed its displeasure at London's and Paris's transfer of LACMs to Kyiv, it did not take any substantive action in response.[86]

US officials are apparently worried an ATACMS transfer could spur Russia to intensify strikes against Ukrainian cities and critical infrastructure, pursue decapitation strikes against Ukraine's leadership and potentially target NATO logistics nodes from which Western equipment is being delivered.[87] Whether Russia has the capability to organise such attacks, however, is doubtful considering its own limitations and Ukraine's growing air and missile defence capabilities. For instance, Russia's earlier attacks were unable to destroy Ukraine's energy network.[88] Moreover, as some of Russia's intelligence, surveillance and reconnaissance (ISR) capabilities appear to be insufficient for near real-time targeting, it is unlikely that Moscow could reliably use its limited technical means to track and target Ukraine's leadership or supply convoys with the necessary level of accuracy needed for these types of strikes.

Washington's hesitancy may actually stem from concerns Russia could seek similar transfers from its own providers, especially Iran. Tehran has supplied

Moscow with large numbers of uninhabited aerial vehicles since Russia's invasion and reportedly planned to supply Russia with *Fateh*-110 and *Zolfaghar* SRBMs, which Iran can produce in large quantities.[89] International pressure on Iran, however, apparently prevented Tehran from following through on this proposal.[90] While Tehran is currently restricted from exporting ballistic and cruise missiles under United Nations Security Council Resolution 2231, this embargo will expire in October 2023, potentially providing Iran with an opportunity to supply Russia with these systems without fear of international sanctions.[91]

Russia has already had to lean on outside suppliers of military equipment to make up for its own shortfalls and to circumvent export controls that have made producing some military equipment difficult, given the heavy reliance in some Russian weapons systems o Western electronics and components.[92] Russia may also seek other suppliers to shore up its own diminishing capabilities. During North Korean leader Kim Jong-un's visit to Russia in September 2023, media reported that arms sales were a topic of discussion.[93] Like Iran, North Korea possesses a large number of SRBMs and an established defence-industrial base for their production.[94]

Beyond any action-reaction dynamics, other possible reasons for Washinton's reluctance to supply Kyiv with ATACMs include the possibility that the US stockpile may be insufficient to provide Ukraine with a number without diminishing US readiness.[95] US officials have refused to disclose how many ATACMS the US Army possesses, but the US Department of Defense has budgeted for 2,121 missiles to be updated between 2017 and 2024 with a new warhead, electronics and propulsion unit, suggesting a possible stockpile number.[96]

Western Rocket Deliveries

Despite Washington's hesitancy to supply Ukraine with ATACMS, the US and other NATO members recognise the important role of stand-off weaponry in the conflict. The US has supplied Ukraine with 38 M142 High Mobility Artillery Rocket Systems (HIMARS) as well as an unknown number of precision-guided rockets.[97] HIMARS is a wheeled launcher that can carry a pod containing six M30 rockets. Other NATO members have also pledged to send Ukraine at least 23 M270 Multiple Launch Rocket Systems (MLRS) of different designs (see Table 1).[98] The M270 is a tracked vehicle that can be equipped with two pods or 12 rockets.

Table 1: **Western equipment delivery of 270mm MLRS variants to Ukraine**

Country	Equipment	Number of platforms pledged	Status of delivery
France	M270A1 MLRS	2	Completed
Germany	M270A1 MLRS (MARS II)	5	Completed
Italy	M270A1 MLRS	2	Completed
United Kingdom	M270B1 MLRS	14	Ongoing
United States	M142 HIMARS	38	Completed

HIMARS High-Mobility Artillery Rocket System; **MARS** *Mittleres Artilleriera-ketensystem* (Medium Rocket Artillery System); **MLRS** Multiple Launch Rocket System.
Source: IISS, *The Military Balance 2023*

While the M30 is typically described as a 'rocket' rather than a 'missile', the system's range, warhead and accuracy blurs the distinction between the two types of equipment. Although there is by no means a consensus among analysts of this difference, rockets are typically understood as being unguided projectiles, while missiles have some capability to be controlled during their flightpath. The M30 is equipped with an inertial measurement unit and GPS guidance, providing it with an estimated CEP of less than 10 m. The system's 70 km-range also places it into the lower threshold of close-range ballistic missiles, classed as having a 60–300 km-range.[99] An extended-range variant is under development with the ambition to double its range to 150 km.[100]

The M142 HIMARS (pictured) has allowed Ukraine to successfully target Russian command and control nodes, troop concentrations, and individual pieces of equipment

(Serhii Mykhalchuk/Global Images Ukraine via Getty Images)

The transfer of MLRS's has allowed Ukraine to successfully target Russian command and control nodes, troop concentrations, and individual pieces of equipment. Russia has struggled in efforts to target MLRS and HIMARS launchers, largely reflecting the limited ISR capabilities of its armed forces and the contested air environment that restricts Russian aircraft from operating deep inside Ukrainian airspace. Despite Russian claims of destroying multiple HIMARS launchers, Moscow has not released any credible evidence to support these claims.[101]

4. Implications for Non-Proliferation Policy and Frameworks

The war in Ukraine has accelerated existing trends in the development, sale, manufacture and employment of precision-strike munitions. These trends were already eroding the existing global framework to account for and limit or control these systems and their related technology.[102] The acceleration of these developments and accompanying erosion of the global framework are resulting in increased access to precision-strike munitions of greater range and lethality by state and non-state actors worldwide.

The relevant existing trends in the development and employment of precision-strike munitions are the following:

- An increased perception among current and prospective operators of the increased military utility of inexpensive precision-guided munitions.
- A decrease in the cost of some missile designs that is congruent with the expansion of capabilities in terms of payload, precision, range and survivability.
- The adaptability of missile designs, including multiple launch modes and the increasing capability of these systems for secondary attack modes against air, sea and land targets.

This section will discuss why each of these trends erodes the ability of national authorities, multilateral export control regimes and norm-setting frameworks to prevent the proliferation of such systems globally.

Increased Perceived Utility

Russia has used short-range ballistic missiles and supersonic anti-ship missiles against land targets relatively successfully in the conflict (although the latter are much less accurate than dedicated land-attack missiles), while subsonic land-attack cruise missiles have performed comparatively poorly. Data released by Ukraine's Ministry of Defence, for instance, states that around 70% to 80% of Russian land-attack cruise missiles launched in large salvos of 20 or more missiles between October 2022 and January 2023 have been intercepted by Ukrainian air and missile defences.[103] In total, Kyiv claims to have intercepted 1,447 cruise missiles since the war began in February 2023.[104] In comparison, Ukrainian military officials have stated that their air defences have been less successful in intercepting short-range ballistic missiles and certain types of anti-ship missiles.[105] Although this data should be treated cautiously, potential reasons for the disparity between successful engagement rates are that ballistic missiles and some types of Russian anti-ship missiles are more difficult to intercept than land-attack cruise missiles (LACMs) because of their high speed and trajectory.

In addition to the widespread use by Russia (and to a much more limited extent by Ukraine) of ballistic and cruise missiles in the conflict, newer and non-traditional systems have been used to tactical effect by both sides. This includes Ukraine's use of US-supplied precision-guided artillery shells as well as both sides' use of modified uninhabited aerial vehicles (UAVs) and dedicated direct-attack munitions.[106] Ukraine's use of asymmetric capabilities against Russia, which was assessed to possess greater military capabilities across all domains at the war's outset is particularly striking, and will likely reinforce thinking in states pursuing asymmetric defence doctrines of the shrewdness of this approach.[107] The apparent success of non-traditional systems might also prompt other states to seek inexpensive systems of proven utility to be used alongside or potentially replace more traditional capabilities and equipment. At the other end of the technology spectrum, the most advanced types of missile technology, including so-called 'hypersonic missiles', have garnered international attention even though they have not been used on a large scale. Their reputation as highly accurate and survivable weapons may have benefited simply from their absence, as well as a lack of analysis and assessment of their effectiveness.[108]

Considering these developments, it is likely that interest among states and non-state actors in acquiring

new types of precision-guided munitions will increase, depending on the buyer's budget and operational requirements. Global production of these systems is also likely to rise in response and the opportunity to field-test equipment on the battlefield will drive innovation among designers, resulting in new systems being developed in increasingly shorter timeframes.[109] States might also prioritise access to a reliable and high-volume supply of established and non-traditional systems, especially because lean defence supply chains have been demonstrated to be insufficient when responding to potential confrontations.[110]

The effect of all these lessons is that, in the future, equipment orders will likely be of higher volume than those before Russia's invasion. Poland's request to purchase up to 500 M142 High Mobility Artillery Rocket System (HIMARS) and associated precision-guided rockets is an example of how significant this upscaling might be for states that wish to better deter their adversaries.[111] Additionally, in the past, states struggled to acquire certain weapons systems, because they were considered too complex to manufacture or off-limits because of export controls. Now, countries that wish to acquire such systems are more likely to believe that they can domestically design and manufacture the equipment if they choose.

Decreased Cost of Certain Higher-level Capabilities

Low-observable cruise missiles and so-called 'hypersonic missiles' have not widely proliferated because of their high cost and difficulty of manufacture. However, the reduced cost of developing some classes of precision capabilities, along with corresponding improvements in range, reliability, mobility, survivability and increased payload capacities of less complex precision-guided munitions, has dangerous implications for the proliferation of related systems.[112] Current conflicts, including those in Ukraine and Yemen, have demonstrated that the manufacture of accurate, long-range precision-guided munitions is relatively easy and inexpensive given enough pressure to technologically innovate at speed. Systems that rely on dual-capable technologies available through civilian markets – the so-called 'Radio Shack cruise missile' – such as the Iranian 351/*Quds* LACM, have demonstrated their utility against adversary infrastructure or equipment even when their targets are well defended.[113] Russia, in response to improved Ukrainian air defences around important political, economic or military sites, has sometimes instead struck less heavily defended targets. When considering lessons from this conflict, more countries and non-state actors are likely to build low-cost systems and adapt their employment techniques to take account of their demonstrated utility in Ukraine.

What's more, state and non-state actors alike, driven by the perceived utility and lower cost of less complex but 'good enough' capabilities, may seek to acquire such systems at scale or manufacture their components on their own. Iran's large-scale supply of one-way UAVs to Russia is a pertinent example, as Moscow has sought to manufacture licensed versions of Iranian direct-attack munitions such as the *Shahed*-136 to increase production and shorten supply chains.[114]

Like Russia, other states are unlikely to rely on other countries for manufacture of such systems, relying instead on domestic production. The spread of the technology, the ubiquity of the components and the low cost of assembly and employment likely will drive a boom in 'cheap and cheerful' systems across the globe with little prospect for international controls.

Adaptable Designs and Target Types

The existing frameworks for limiting the spread and holdings of ballistic and cruise missiles and uninhabited aerial vehicles are dependent on outdated definitions that have been challenged, if not obviated, by trends in technology.[115] This problem is apparent across many of the different aspects of the existing definitions key to identifying specific types.

Ballistic Missiles

Ballistic missile control in international agreements is predicated on the idea that such missiles are so inaccurate that they must be purpose-built to deliver weapons of mass destruction since they are not precise enough to destroy their target with a conventional warhead. Thus, the Missile Technology Control Regime (MTCR) defines Category I missiles, the export of which are subject to

a strong presumption of denial, as those systems that can travel more than 300 kilometres with a payload of more than 500 kilograms.[116] When the MTCR's guidelines were drawn up in the late 1980s, they were based on contemporary Soviet missile designs, particularly the R-300 *Elbrus* (RS-SS-1C *Scud* B) SRBM that the Soviet Union had widely exported. The *Scud* B has a range of 300km, a Circular Error Probable (CEP) of 900 metres and can be equipped with a payload of up to 985kg.[117] The missile's poor accuracy was not seen as an impediment for it to damage or destroy the intended target if it were equipped with a nuclear warhead which would cause widescale destruction. However, if an operator tried to use the missile against small targets with a conventional warhead, the missile's inaccuracy would mean that it would very likely miss and not achieve the desired effect.[118] Some newer ballistic missile designs have CEPs as small as ten metres and are thus capable of delivering significant damage to small targets with a high degree of precision. Even some types of older ballistic missiles can be modified with and retrofitted with improved, relatively inexpensive internal and external guidance to greatly improve their accuracy.[119] Thus, the definition of controllable ballistic missiles – defined as being capable of delivering a nuclear payload at distance – is becoming increasingly irrelevant to limiting the spread of short-range, highly-accurate conventional missiles.

Launch and Attack Modes

The other major definitional challenges posed by evolving trends in missile technology is the adaptability of designs, including multiple launch modes and the increasing use of such systems for secondary attack modes. Missiles that were originally designed to be launched from one type of platform (aircraft, maritime vessels or ground launchers) have frequently been adapted to be launched from other platforms to improve the equipment's utility and increase commonality across service branches. The US-designed AGM-84A *Harpoon* anti-ship missile, for instance, was originally designed in the early 1970s to be launched from surface vessels, but it has since been adapted for launch from multiple different types of aircraft, ground launchers and submarines.[120]

While many types of missiles are only capable of striking a single type of target due to the inclusion (or absence) of specialised guidance technology, more modern designs have adopted improved seeker technology, enabling the missile to be used for primary and secondary attack modes. The *Harpoon*, for instance, was modified to attack land targets, resulting in the creation of the AGM-84E Standoff Land Attack Missile (SLAM). While adapting missile designs for different purposes is not new, the war in Ukraine has amply illustrated how rapidly that can happen. Both Ukraine and Russia have adapted air-defence and anti-ship missiles for land-attack missions with varying degrees of success.[121] Russia also has made the ability to adapt missiles across platforms a feature of its development programme.

The multi-use nature of some types of missiles today means that the traditional arms control approach of limiting ground-launched ballistic and cruise missiles of a certain range while excluding air- and sea-launched systems – as was the case in the Intermediate-Range Nuclear Forces (INF) Treaty – would be impossible in current circumstances. If any air- or sea-launched missile can be adapted for ground launch mode and vice-versa, and the air- and sea-launched versions are excluded from the treaty, the possibility of signatories violating the agreement will be unlimited and verification will become impossible. The same holds true if an anti-air or an anti-ship missile can be used to accurately strike ground targets. At the same time, the mobility of air- and sea-launched cruise missiles would greatly complicate any effort to verify the number and location of these systems, given that inspections on airbases and ports would be considered highly intrusive to the everyday running of these facilities and because platforms can quickly and easily be moved ahead of inspections. A future treaty aiming to restrict certain categories of guided weapons would therefore need to address a much wider range of systems than the original INF agreement.

Ramifications

The confluence of factors described above create a bleak outlook for the future control of such missile systems. Indeed, it appears that an increasing number of states and non-state actors alike will be able to acquire or manufacture their own precision-guided munitions of increasing effectiveness (whether through better technology or sheer numbers) over time. Adapting existing

agreements, such as the Missile Technology Control Regime (MTCR) and norm-setting frameworks such as the Hague Code of Conduct (HCoC) would be both technically complex and politically difficult (if not impossible) considering the broader context of Russia and the war. This challenge does not even take into account that many of the countries of highest proliferation concern, including China, Iran and North Korea, are outside of the MTCR and the HCoC while some members, such as Russia, ignore its obligations.[122]

Conclusion

Russia's full-scale invasion of Ukraine has provided Moscow with an opportunity to field test multiple types of ballistic and cruise missile systems, building on some of the lessons it likely learned during its intervention in Syria in 2015. The war has also served as a test for the Russian forces' adherence to the State's official military doctrine, which they appear to have strayed from. Most glaringly, Moscow has not prosecuted high-value targets with the intensity required to achieve the quick military victory that their doctrine envisions and that Moscow appears to have planned for.

While Russian short-range ballistic missiles have performed relatively well against Ukrainian air defences, the limited use of these type of systems at the outset of the war left key Ukrainian military and command and control targets largely unscathed. Land-attack cruise missiles (LACMs) – especially subsonic systems – appear to have suffered from high failure rates but have benefitted from being supplemented by large numbers of relatively inexpensive direct-attack munitions which Moscow acquired from Iran. Newer and non-traditional systems have also been employed with tactical effects by both sides, highlighting the adaptability and versatility of some designs.

Moscow could draw multiple lessons from the use of ballistic and cruise missiles in Ukraine. For one, that its antebellum inventory of LACMs was insufficient and this shortfall proved detrimental in the early stages of the war. Moscow has since made efforts to increase missile production rates. The war will also almost certainly further fuel Russia's drive to develop additional high-supersonic LACMs that have performed better against air defences as well as Mach-5 plus systems. Russia's procurement and production of large numbers of slow and cheap direct-attack munitions and adaption of missile designs for use as decoys highlight the importance of mass as a means of survivability.

Other states are also carefully examining both sides' performance in Ukraine for lessons on the employment of long-rang strike capabilities. Despite their mixed success rate, Russia's use of missiles and non-traditional systems as well as Ukraine's employment of asymmetric capabilities will likely increase their perceived military utility in the eyes of many state- and non-state actors. The falling cost of developing some classes of precision capabilities, especially less-complex systems that rely on dual-use technologies available through civilian markets, suggests an easy possibility of proliferation, dependent on user's requirements and resources. State and non-state actors may seek to acquire such systems at scale, but likely pursue domestic production capability in the future.

Ultimately, Russia's war in Ukraine will have wide ramifications for existing arms- and export-control regimes. As certain types of guided weapons become both more attractive and increasingly available, current agreements such as the Missile Technology Control Regime and the Hague Code of Conduct against Ballistic Missile Proliferation may increasingly face technical and political obstacles that challenge their usefulness. Likewise, the multi-use nature of some types of missiles means that traditional arms-control approaches, such as limiting ground-launched systems of a certain range while excluding air- and sea-based systems, will become increasingly untenable. A future treaty aiming to restrict certain categories of guided weapons would therefore need to address a much wider range of systems than in the past which would prove a challenge even in a much healthier political environment.

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117 CEP is a simple measure of a weapon system's accuracy. It is defined as the radius of a circle into which a missile, projectile or bomb will land at least half the time. For further information on the *Scud* B's characteristics, see: Federation of American Scientists, 'R-11 / Ss-1b Scud-A R-300 9k72 Elbrus / Ss-1c Scud-B'. 9 September 2000, https://nuke.fas.org/guide/russia/theater/r-11.htm.

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