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DIALOGUE
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MISSILE TECHNOLOGY: ACCELERATING CHALLENGES

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INTERMEDIATE-RANGE 3000–5500km
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an IISS strategic dossier

MDI Missile Technology: Accelerating Challenges

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Contents

Common abbreviations

ABM	anti-ballistic missile
ABM Treaty	Anti-Ballistic Missile Treaty
ALBM	air-launched ballistic missile
ALCM	air-launched cruise missile
ARRW	air-launched rapid response weapon
ASCM	anti-ship cruise missile
ATACMS	army tactical missile system
BCC	Bilateral Consultative Commission
CALCM	Conventional Air Launched Cruise Missile
CCP	Communist Party of China
CEP	circular error probable
CPMIEC	China Precision Machinery Import-Export Corporation
CFE Treaty	Treaty on Conventional Armed Forces in Europe
CMC	Central Military Commission
C-HGB	common-hypersonic glide body
CPS	conventional prompt strike
CRBM	close-range ballistic missile
DIA	Defense Intelligence Agency
DSMAC	digital scene matching
FBS	forward-based systems
FCASW	Future Cruise/Anti-Ship Weapon
GLCM	ground-launched cruise missile
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HALO	hypersonic air-launched offensive anti-surface warfare
HACM	Hypersonic Attack Cruise Missile
HAWC	Hypersonic Air-Breathing Weapon Concept
HCM	hypersonic cruise missile
HCoC	Hague Code of Conduct
HGV	hypersonic boost-glide vehicle
HIMARS	High-Mobility Artillery Rocket System
ICBM	intercontinental ballistic missile
IEM	Information Exchange Meeting
IIR	imaging infrared
INCSEA	1972 Agreement on the Prevention of Incidents On and Over the High Seas
INF Treaty	Intermediate-range Nuclear Forces Treaty
IRBM	intermediate-range ballistic missile
INS	inertial navigation system
JASSM	joint air-to-surface standoff missile
JASSM-ER	joint air-to-surface standoff missile extended range
JSSCM	Joint Supersonic Cruise Missile
LACM	land-attack cruise missile
LEEM	Licensing and Enforcement Experts Meeting
LEP	life-extension programme
LRA	long-range aviation
LRHW	Long-range Hypersonic Weapon
LRSO weapon	Long-Range Stand-off weapon
MaRV	manoeuvrable re-entry vehicle
MdCN	Missile de Croisière Naval
MEL	mobile erector launcher
MIRV	multiple independently targetable re-entry vehicle
MLRS	multiple launch rocket system
MRBM	medium-range ballistic missile

MRC system	Mid-Range Capability system
MTCR	Missile Technology Control Regime
NMD	national missile defence
NNSA	US National Nuclear Security Administration
NFU	No First Use
NSA	non-state actor
NSNW	non-strategic nuclear weapon
NTM	National Technical Means
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
PLARF	People's Liberation Army Rocket Force
PrSM	Precision Strike Missile
RPOC	Reinforced Point of Contact
RF	radio frequency
SALT	Strategic Arms Limitation Talks
SAM	surface-to-air missile
SLBM	submarine-launched ballistic missile
SRBM	short-range ballistic missile
START	Strategic Arms Reduction Treaty
SLCM-N	Nuclear-armed Sea-launched Cruise Missile
SORT	Strategic Offensive Reductions Treaty
SSBN	nuclear-powered ballistic-missile submarine
SSD	strategic stability dialogue
SSGN	nuclear cruise missile submarines
SSM	surface-to-surface missile
TEL	transporter erector launcher
TEM	Technical Experts Meeting
TERCOM	terrain contour matching
THAAD	Terminal High Altitude Area Defense
TLAM	Tomahawk Land-attack Missile
TOM	Technical Outreach Meeting
TSSAM	Tri-Service Standoff Attack Missile
USAF	United States Air Force
USSTRATCOM	United States Strategic Command
UUV	uninhabited underwater vehicle
USN	US Navy
VLS	vertical launch system
VPT	Virginia Payload Tube
WMD	weapon of mass destruction

Introduction

Missiles have been a formidable and sought-after instrument of state power since their conceptualisation. Although the ballistic and cruise missiles developed and used in the Second World War mostly failed to achieve the objectives of their earliest operators, the use of these systems as weapons of terror against civilian populations nonetheless demonstrated their potential application as tools of coercion and deterrence. The limited use of early types of guided weaponry also displayed the advantages of using unmanned platforms to target an opponent's military forces at a distance that did not risk operating personnel or platforms. Because of the limitations of early guidance systems, ballistic and cruise missiles that were designed between 1945 and the mid-1980s were mostly utilised in counter-value roles to target civilian populations with biological, chemical or nuclear warheads, also known as weapons of mass destruction (WMD). The association between ballistic and cruise missiles and WMD is particularly strong because, in light of the poor accuracy of early types of these systems, only the large-scale devastation caused by WMD allowed operators to be reasonably confident of destroying the target. This association has been manifested through the rationale of many multilateral arms-control and non-proliferation mechanisms established during the latter part of the Cold War, including the Missile Technology Control Regime (MTCR), the Hague Code of Conduct (HCoC) and United Nations Security Council Resolution 1540.

Though still relevant, the connection between missiles and WMD has weakened due to technological and navigational revolutions that have significantly improved possible accuracy, which has in turn increased the utility of these weapon types as conventional war-fighting tools. Against this backdrop, the proliferation trends during the 1990s and early 2000s – when the world community was able to incentivise against proliferation and ensure there were fewer missile operators – halted and, in recent years, have been reversed. Missile proliferation has not been limited solely to the number of operators, but also to the number of types of missile that are in service. In 2002, for instance, there were 42 types of ballistic missile in operation globally; by 2022 that number had jumped to 83. The reason for this trend is partly that some operators, such as Iran and North Korea, have developed and deployed multiple variants of similar systems. However, this figure also reflects greater national interest in developing systems that can be used in conventional war-fighting roles. In addition, uninhabited aerial vehicles (UAVs) capable of delivering warheads have also increased in accuracy, range, speed and ubiquity. Most disturbingly, the line between a cruise missile – a one-way warhead-delivery system – and UAVs – some of which can release weapons and return to base, some of which can strike a target much like a missile does – has become blurred and will probably continue to become more so in the future.

This obfuscation of guided-weapon categories is part of a broader trend of technological innovation, imitation and adaption. Across all types of missiles, the limitations imposed through export- and arms-control frameworks have bred innovation on the part of buyers and producers to avoid these limits. At the top end of the spectrum, the most advanced states can drive the development of sophisticated technologies and new technologies to improve warhead delivery and accuracy, as well as missile speed, survivability, readiness, integration and range, through various types of advanced research. Some of these improvements may be the result of commercial efforts, such as developing new means of propulsion for faster civilian transportation. In the middle of the spectrum, less advanced states that lack the access and resources to access the upper end of the spectrum adapt these new technologies to create similar but less refined systems, or develop adaptations. These alternatives and adaptations are then further modified at the lower end of the spectrum by less technologically capable states and non-state actors (NSAs) seeking to create novel or strategic effects on the battlefield. Thus, technological innovation drives the development of new weapons, which in turn is adapted to new tactics, which in turn pushes down costs and widens access, leading to arms racing. So-called 'kamikaze drones' are one example of this new dynamic as they essentially act as low-budget land-attack cruise missiles.

The ability of the existing arms- and export-control regimes to adapt to these new dynamics is limited. They instead focus on the mid- to high-range capabilities, such as traditional UAVs and ballistic and cruise missiles. They do not address rapid technological innovations and in fact incentivise innovation, allowing states and NSAs to access the benefits of longer-range delivery systems that pose little operator risk. The innovation gap and time lag in arms and export control is becoming more apparent and serious as countries across the technological spectrum are developing new types of guided weaponry, as well as adapting and imitating systems and techniques to achieve their political and military objectives at a lower risk and cost. Nor do arms and export controls take into account that this traffic is not just one way: for instance, as part of Russia's war on Ukraine, we see a technologically advanced state (Russia) procuring and adopting lower-end technology from a less developed state (Iran) to augment its existing precision-strike capabilities and attempt to overwhelm its opponent's air and missile defences. The MTCR's efforts to prevent the proliferation of advanced types of guided weapons from technologically advanced to less developed states by setting range and payload thresholds (among other restrictions) are largely ineffective when the reverse happens, either because the producer is not a member state or because the equipment does not meet export-restriction thresholds or has dual military and civilian uses and as such is not as tightly restricted. The need to reform the existing global and regional arms-proliferation-limitation regimes to account for these new dynamics is clear.

This dossier has been published under the auspices of the Missile Dialogue Initiative (MDI), a Track 1.5 programme that was initiated by Germany's former foreign minister Heiko Maas within the context of Germany's 'Capturing Technology. Rethinking Arms Control' endeavour. The project commenced under the stewardship of the International Institute for Strategic Studies (IISS) in 2019, when it was becoming apparent that arms control and non-proliferation would be under significant strain for the foreseeable future. The resumption of great-power competition between China, Russia and the US and the desire of each of those states to secure a technological advantage over its rival(s) have reduced their willingness to be constrained by these arms-control and non-proliferation measures. This reluctance is reflected through decisions and actions that have been taken since the project's inception. This includes China's persistent refusal to engage in arms-control discussions, despite – or perhaps because of – incontrovertible evidence that it is embarking upon a significant expansion of its nuclear forces; Russia's deliberate violation of the Intermediate-Range Nuclear Forces (INF) Treaty with the development of the 9M729 (RS-SSC-8 *Screwdriver*) ground-launched cruise missile; and the United States' abandonment of the Treaty on Open Skies. While there is still some desire on the part of Russia and the US to limit the size of some parts of their missile forces, both have also sought to find ways around these agreements by developing new types of offensive and defensive missile technologies that are not bound by treaty constraints. The development of new technologies and the resulting action–reaction cycles have also raised questions about and reduced confidence in the ability of existing agreements, including the New Strategic Arms Reduction Treaty (New START), to adequately capture these systems. Whether existing agreements will be able to withstand the stresses imposed by new technologies remains to be seen.

Beyond the increasingly competitive relationship between China, Russia and the US, other states are also pursuing the development of ballistic and cruise missiles, sometimes with the goal of achieving unilateral security without considering the potential consequences for regional security that these programmes might entail. This includes the development of so-called 'low-end' systems that are being produced wholesale by some countries. It is debatable whether existing arms- and export-control agreements can even restrain, let alone halt or roll back, the development of some of these low-end technologies.

Against this backdrop, the MDI has endeavoured to act as an international platform and clearing house to strengthen international discussion and promote high-level exchanges of views on missile technologies and related international security dynamics. By creating an international network of analysts and policymakers, and by publishing in-depth research, the MDI seeks to help inform and contribute to state-level discussions of required policy responses. As governments look for new ways to address strategic arms-control developments and the potential impact of missiles and missile-related technologies on these strategies, the MDI brings together a global expert community to identify and discuss these challenges. Between 2019 and 2022, the MDI has published multiple research papers and analysis pieces in collaboration with world-leading experts, and organised a series of Track 1.5 conferences in various locations in different regions that has brought together senior officials from governments and multilateral organisations concerned with arms and export control. This dossier is a culmination of those efforts.

Missile Technology

CHAPTER ONE

Range Matters

The evident military utility of Germany's V-2 ballistic missiles during the Second World War galvanised efforts by the Soviet Union and United States to accelerate their respective nascent ballistic-missile programmes in the immediate post-war period. Although early Soviet and US efforts initially focused on reproducing and improving captured German designs, once both nations had mastered and refined the basic principles behind ballistic-missile technology each sought to develop systems with increasingly greater ranges. Within a decade of the development of the Soviet Union's first ballistic missile – the 300-km-range R-1 (RS-SS-1 *Scunner*) – in 1948, the Soviet Union had produced its first intercontinental ballistic missile (ICBM), the 7,000 km-range R-7 *Semyorka* (RS-SS-6 *Sapwood*).

The challenge of designing ballistic missiles that can travel long distances (in this context, meaning several thousand kilometres) has meant that range has often been used as a yardstick of a state's missile programme. Resultingly, range is often one of the biggest – if not the biggest – sources of concern for policymakers. Incremental increases in the range of Iranian and North Korean systems, for example, have sometimes acted as catalysts for the implementation of multilateral sanctions, efforts to tighten export controls, or the deployment of defensive missile systems in response.

Whilst it may appear inevitable that countries with ballistic-missile programmes will develop successively longer-range systems, this is not always the case. Some states have unilaterally decided or bilaterally agreed to restrict the range of these weapons for economic, political and security reasons. For instance, it is unlikely that Islamabad will increase the range of its longest-range ballistic missile – the *Shaheen*-III – as its 2,750-km range allows Pakistani forces to strike targets across India.

From Islamabad's perspective, developing longer-range systems is neither cost-effective nor needed, unless Pakistan's security outlook radically changes.

Instead, it is likely that Pakistan will concentrate on improving other facets of its missile forces, such as precision, survivability and readiness.

Other states, such as Iran, have also made unilateral decisions to restrict the range of their missile forces to concentrate on other priorities.

Key takeaways

ENHANCED EFFICACY

Various technological developments have improved the efficacy and credibility of multiple states' ballistic-missile forces. A broader consideration of advances in missile technology will provide policymakers with a better understanding of the implications of these systems.

BALLISTIC PROLIFERATION

Between 2002 and 2022, the number of different types of ballistic missiles that are in service across the globe has almost doubled from 42 to 83. Given development and deployment trends, it is likely that ballistic missiles will be increasingly used in conventional war-fighting roles.

HGV CHALLENGES

Due to the challenges associated with the development of hypersonic boost-glide vehicles, it is likely that proliferation in the near term will be limited to a handful of technologically advanced and wealthy states.

OUTDATED LEXICON

Technical developments of cruise-missile technology have outstripped the lexicon, leaving room for misunderstanding, misidentification or misrepresentation. All three are of importance for the arms-control arena.

HIGH-SPEED CRUISE

While there is much that remains uncertain and, additionally, much that remains classified, what is apparent is that several countries are now pursuing research and development into Mach 5+ cruise missiles.

For Tehran, increasing the precision and size of its arsenal is more important, as accuracy enhancements mean that in the event of a conflict Iranian forces can better hold regional military targets at risk.

As well as developing new systems, Tehran has also improved the precision of older systems, such as the *Fateh*-110 short-range ballistic missile (SRBM), by upgrading them with terminal-guidance packages.

Even though some elements of Iran's arsenal are still somewhat inaccurate, the depth and scope of Tehran's missile arsenal means that even inaccurate and shorter-range systems have some military value in a conflict, as repeated salvos will likely result in sporadic hits and force defenders to expend limited numbers of interceptors to defend military facilities and civilian infrastructure.

While range is not the only issue of concern for policymakers, other areas of ballistic-missile design, such as improved precision or survivability, have arguably received less attention. While technological advancements have sometimes been the focus and bane of arms-control efforts, these have typically concerned strategic missile forces or so-called 'novel' capabilities, such as hypersonic boost-glide vehicles (HGVs), which will likely only be accessible in small quantities.

By overlooking technological developments at the lower end of the range spectrum, policymakers are at risk of underestimating how advancements in this area may improve the efficacy and credibility of a potential adversary's missile forces. Instead, a broader consideration of advances in missile technology will provide policymakers with a better understanding of the stability implications of these systems and how more effective diplomatic and military responses can be crafted in response.

Moving Warheads

Ballistic missiles provide their operators with a means to project power over distances. The development and deployment of these systems have historically been associated with biological, chemical and nuclear payloads, as the inaccuracy of early ballistic missiles meant that they were unsuitable for precision strikes with conventional warheads.

The historic association between ballistic missiles and weapons of mass destruction has meant that multilateral export controls and norm-setting mechanisms continue to intrinsically link these two elements. The Hague Code of Conduct, for instance, asks subscribing states to recognise the need 'to prevent and curb the proliferation of Ballistic Missile systems capable of delivering weapons of mass destruction' and 'to exercise maximum possible restraint in the development, testing and deployment

WHITE SANDS MISSILE RANGE
Launch of a German V-2 sounding rocket (an example of imported German expertise and technology that was instrumental to the United States' and the USSR's early ballistic-missile programmes), March 1951. CREDIT: Schenectady Museum Association/Corbis Historical/Getty Images.

of Ballistic Missiles capable of delivering weapons of mass destruction'.

Similarly, the Missile Technology Control Regime (MTCR) Guidelines state that the purpose of the agreement is to 'limit the risks of proliferation of weapons of mass destruction … by controlling transfers that could make a contribution to delivery systems … for such weapons'.

Despite this linkage, the association between ballistic missiles and weapons of mass destruction is gradually weakening. Although ballistic missiles were widely utilised for the delivery of offensive biological and chemical weapons during the Cold War, these programmes have since mostly been dismantled through unilateral decisions or multilateral arms-control agreements.

While ballistic missiles continue to be the delivery mechanism of choice for nuclear weapons, some states are diversifying the delivery options of their nuclear weapons in order to evade existing missile defences. Russia is developing a nuclear-armed uninhabited underwater vehicle known as *Poseidon* (*Kanyon*) in order to hedge against this perceived threat.

Finally, technological advancements – especially in guidance technology – mean that ballistic missiles are also increasingly being utilised as conventional weapons.

Although the utility of using existing intermediate-range ballistic-missile (IRBM) and ICBM designs for conventional missions is questionable, there has been significant vertical and horizontal proliferation of close-, short- and medium-range ballistic missiles (respectively, CRBMs, SRBMs and MRBMs) over the last ten years. This has reversed proliferation trends set between 2002 and 2012 in which there was a reduction in the number of ballistic-missile operators, partly due to the retirement of Soviet equipment from aspiring NATO members in Eastern Europe.

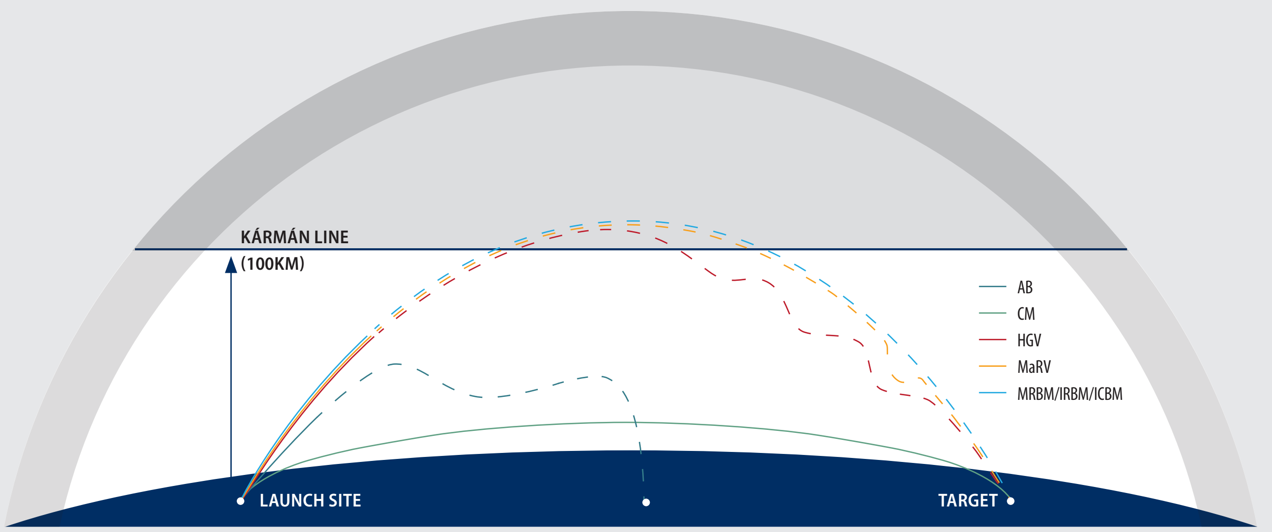
Currently, only six states operate ICBMs, with a seventh – India – likely to possess this capability within the next five years.

As precision accuracy is difficult to achieve over longer ranges, all ICBM operators have armed these systems with nuclear warheads. At the other end of the spectrum, an estimated 27 states and two non-state actors (NSAs) – Ansarullah and Hizbullah – operate at least one type of ground-launched conventional CRBM, SRBM or MRBM, with the number of operators likely to further increase within the next decade given planned procurements.

Strikingly, from 2002–22, the number of different types of ballistic missiles that are in service across the globe has almost doubled from 42 to 83.

While some of these newly produced systems are solely designed to deliver nuclear warheads, the majority are conventionally armed shorter-range ballistic missiles. Given development and deployment trends, it is likely that ballistic missiles will be increasingly used in conventional war fighting, much in the same way that cruise missiles have evolved from nuclear to conventional missions.

Figure 1.1: **Ballistic- and cruise-missile flight paths**



AB: aero-ballistic missile. CM: cruise missile. HGV: hypersonic boost-glide vehicle. MaRV: manoeuvrable re-entry vehicle.
MRBM/IRBM/ICBM: medium-range, intermediate-range and intercontinental ballistic missiles.

Note: For illustrative purposes only. Not to scale.
Source: IISS

Diverging Flightpaths

In the classical sense, a ballistic missile follows a predictable parabolic ballistic trajectory to its target that is comprised of three distinct sequences:

1. A boost phase, during which the ballistic missile uses rocket propulsion to propel the rocket to an altitude which is usually outside the Earth's atmosphere and provide it with the velocity needed to reach its intended target.
2. The midcourse phase, where the missile, having exhausted its fuel, travels along a predetermined trajectory, outside the Earth's atmosphere, toward its target.
3. A terminal phase, wherein the missile re-enters the Earth's atmosphere under the force of gravity and strikes its target.

These sequences provide a neat taxonomy, with arms-control treaties such as the New Strategic Arms Reduction Treaty (New START) having identified this as the defining feature of ballistic missiles, setting them apart from other types of guided weapons, such as cruise missiles.[1]

Although modern ballistic missiles may appear externally similar to earlier delivery vehicles, many types of newer (and some older) designs do not utilise traditional parabolic ballistic trajectories comprising these three phases. Advances in key technological areas, including aerodynamics, airframes, guidance, delivery vehicles and propulsion, have made new flightpaths possible, thereby rendering this sequence increasingly tenuous. For instance, although manoeuvrable re-entry vehicles (MaRVs) utilise rocket propulsion during the boost phase and travel on exo-atmospheric trajectories during the midcourse phase, the utilisation of conical-shaped warheads equipped with control surfaces provides the warhead with the capability to conduct cross-range manoeuvring within the Earth's atmosphere during the terminal phase of flight.[2]

Other types of ballistic missiles, such as HGVs, take this concept one step further, as almost the entire flightpath takes place within the Earth's atmosphere. HGVs are also capable of making more extensive vertical and lateral manoeuvres than so-called 'traditional' ballistic missiles. Because of the significant time spent within the atmosphere, these flightpaths are, in some respects, more like the endo-atmospheric flightpaths utilised by cruise missiles. This feature is not exclusively utilised by HGVs, as some shorter-range systems, such as the Russian *Iskander*-M (RS-SS-26 *Stone*) SRBM and the US MGM-140A Army Tactical Missile System (ATACMS), remain entirely within the Earth's atmosphere throughout their flightpath. Aero-ballistic missiles can also manoeuvre laterally and vertically, although this capability is likely more limited than that of an HGV.[3] Other longer-range systems such as Russia's *Kinzhal* (RS-AS-24 *Killjoy*) air-launched aero-ballistic missile are also thought to utilise purely endo-atmospheric flightpaths.

While the muddling of definitions brought about by technological evolutions may appear to be purely grammatical, analysts have observed that this can create blind spots for existing arms-control and non-proliferation mechanisms and incentivise cheating to circumvent restrictions based on static definitions.[4]

GUIDANCE TECHNOLOGIES
Ring-laser gyroscopes, among other components, increase the accuracy of modern ballistic missiles. CREDIT: Pallava Bagla/Corbis News/Getty Images.

Improved Accuracy

Early guided ballistic missiles relied on external control surfaces such as tail fins, wings and canards, as well as inertial navigation systems (INSs), typically in the form of mechanical gyroscopes, to keep the missile on its planned trajectory toward the intended target.[5] In these systems, gyroscopes and lateral accelerometers provide a missile with a means to measure its orientation and acceleration, which internal computers use to provide commands to control surfaces and jet vanes to steer the missile toward its target.

The limitations of early guidance equipment meant that maintaining accuracy over long distances was particularly challenging, and the circular error probable (CEP) of many early Soviet and US ballistic missiles was often measured in kilometres rather than metres.[6] This limited the number of potential targets to large, fixed sites, such as urban areas, ports and airfields. It also necessitated equipping many missiles with a nuclear warhead to ensure the target's destruction.[7] The constraints of early guidance technology also provided limited recourse for correcting external influences that can affect a missile's accuracy over long ranges, such as atmospheric variations (including wind and atmospheric density), inexact engine cut-off (which can cause the missile to under- or overshoot the target) and vehicle asymmetries caused by asymmetric ablation, with the result that a target could be missed by a large distance.[8]

Modern ballistic missiles utilise far more sophisticated INSs for guidance as compared to these early missile designs. Along with these, advances in midcourse- and terminal-guidance technologies have improved the precision of many contemporary systems. Of the more accurate shorter-range systems in service for conventional war fighting, some, such as the United States' ATACMS SRBM, can be used to strike small, fixed targets, such as individual buildings and items of military equipment.[9] Other longer-range systems, such as China's DF-26 IRBM, appear to be capable of striking moving targets, such as maritime vessels.[10]

Achieving this level of accuracy requires designers to incorporate multiple types of guidance packages into missile designs, as well as active and passive seekers for target identification. Global Navigation Satellite Systems (GNSSs), such as the United States' Global Positioning System (GPS) or Russia's Global Navigation Satellite System (GLONASS), have provided ballistic-missile operators with a valuable secondary means of navigation. GNSS can improve missile accuracy by allowing the INS to cross-check its data on the missile's position and make adjustments if necessary. GNSS can also improve pre-launch survivability as it reduces the need for time-consuming alignments of the missile's inertial-measurement unit prior to launch.[11] As GNSSs can be blocked or jammed and have limited uses against moving targets, developers might also incorporate other forms of terminal guidance, such as electro-optical, radar and infrared seekers, that can be used to track and home in on moving targets during the terminal phase.

At longer ranges, specialised types of guidance equipment have been developed to make use of exo-atmospheric flightpaths. Stellar navigation was initially utilised by US aerospace manufacturer Northrop in the 1950s for use aboard the United States Air Force's (USAF) SM-62 *Snark*, an intercontinental-range cruise missile that briefly saw service in the 1950s and 1960s.[12] Stellar navigation guides a missile toward its target by locking onto the location of a star with respect to positions on the Earth's surface at any given time. By comparing this measurement against the missile's internal-guidance system, celestial navigation can provide corrective adjustments to ensure increased accuracy. Although *Snark* was retired, stellar-aided INSs have subsequently been applied to ballistic missiles, such as the US/United Kingdom *Trident* I (C4)/II (D5) submarine-launched ballistic missile (SLBM), amongst others.[13] Stellar navigation also provides operators with an invulnerable means of guidance that cannot be hacked or jammed, which is especially useful in contested environments.[14]

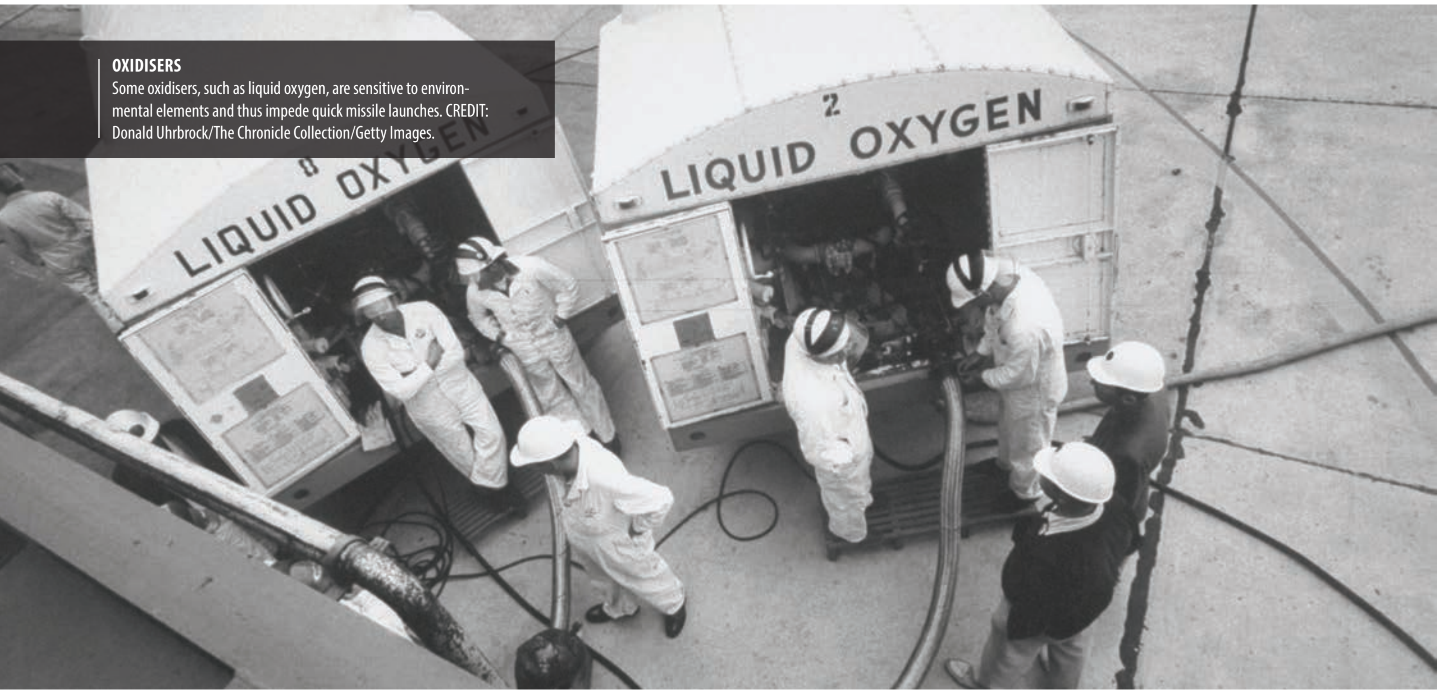
Unlike mechanical gyroscopes, which are sensitive to external forces – such as vibrations that can disturb components and the accuracy of measurements – modern components such as optical gyroscopes and gas-bearing gyroscopes are more compact, reliable and accurate. As a result, these have been incorporated into some modern ballistic systems.[15] Small and lightweight components also have the added benefit of reduced weight, which can allow for the installation of larger fuel tanks or a heavier warhead, thereby improving the missile's range or its destructive power.

Fuelling Propulsion

Advancements in rocket propulsion have been less striking than those in other areas of ballistic-missile design due to the limited choice of propellants available to designers. Despite this, designers have made efforts to refine existing technology and make adjustments where possible.

Advances in rocket propellants – especially with the increasingly widespread use of solid fuels beginning in the mid-twentieth century – have improved the utility of ballistic missiles as both nuclear and conventional weapons by reducing launch-preparation times. Whereas some early systems, such as the R-17 *Elbrus* (RS-SS-1C *Scud*-B), might require around one hour and multiple support vehicles to prepare the missile for launch, some modern systems, such as Russia's *Iskander*-M SRBM, can be launched in as little as four minutes and with as few as three personnel.[16]

Almost all ballistic missiles utilise either liquid or solid fuels, although there are some hybrid designs that utilise both types.[17] A liquid-fuelled system's propellant consists of a separate fuel and an oxidiser. Fuels are typically kerosine, alcohol or a type of hydrazine.[18] As with fuels, there are a limited number of suitable oxidisers, with nitric acid and nitrogen tetroxide being most commonly selected by designers. Because fuel and oxidisers react when they are mixed, they are stored in separate pressurised tanks prior to the missile's launch. During launch and during the fuelled portion of the missile's flight they are transferred to the combustion chamber using powerful turbopumps where, depending on the type of propellant chosen, they ignite either spontaneously upon contact or through an igniter. This generates energy that is ejected out of the combustion chamber at high speed, thus producing thrust.[19] Because storing liquid propellants in tanks for long periods of time is difficult due to various materials-science problems – such as corrosion to fuel tanks – most liquid-fuelled ballistic missiles can only be fuelled immediately prior to launch.



OXIDISERS
Some oxidisers, such as liquid oxygen, are sensitive to environmental elements and thus impede quick missile launches. CREDIT: Donald Uhrbrock/The Chronicle Collection/Getty Images.

Solid-fuelled missiles are comparatively simpler than their liquid counterparts, as solid propellants are easier to store and the engine is less mechanically complex. In a solid-fuel system, the fuel and oxidiser are pre-mixed and poured into a chamber with a bonding agent where they form a solid resin. Solid-fuel systems are mostly limited to using two types of propellant: nitrocellulose and nitroglycerine, or composite propellants formed of ammonium perchloride, aluminium powder and a binding agent to harden the resin.[20] Once the solid propellant is set, the fuelled missile can then be stored until it is launched. Solid-fuel technology has progressed minimally since discoveries in the mid-twentieth century improved fuel composition and thrust.[21] Mixing, casting and curing propellants is a difficult task, hence why liquid-fuel technology is often initially pursued by states with domestic ballistic-missile aspirations, despite the drawbacks of lengthy launch times.[22] As there are limited options for controlling the burn rate of a solid-fuel engine once it is ignited, there are restricted options to throttle the missile.

Despite the limitations to further refining both types of propellants, designers have sought to make improvements where possible, especially if this will reduce the missile's launch-preparation time. Shortening this process is beneficial for operators as it reduces the window of opportunity in which an adversary may detect and potentially destroy a missile before it is launched. Reducing launch-preparation times also provides users with the ability to launch missiles at short notice, which is valuable for silo-based nuclear forces which might need to be launched with very little warning time.[23] Missiles that can be pre-fuelled and stored for long periods of time are also more appropriate delivery vehicles for SLBMs, given the difficulties of fuelling missiles whilst at sea or at remote submarine bases.

Among liquid-fuel systems, one area of development is in the use of certain oxidisers. Liquid oxygen was used in several early missile designs, such as the German V-2 and Soviet R-Z, as it creates a high specific impulse. However, its chemical properties mean that it needs to be stored at cryogenic temperatures, which makes it difficult to handle, store and maintain.[24] As a result, designers began to use more stable oxidisers that could be stored at room temperature. Fuel ampoules provide another means to reduce launch times. Ampoulisation was first used by the Soviet Union in the design of the silo-based RS-10 (RS-SS-11 *Sego*) ICBM that was deployed in 1966. Ampoulisation includes a number of design and technological measures, such as sealing fuel tanks and lines, amongst others. This allows the missile to be fuelled, stored and loaded into its silo or submarine launch tube for significant periods of time prior to launch.[25] Several Russian systems, such as the silo-based RS-20 (RS-SS-18 *Satan*) and RS-18 (RS-SS-19 *Stiletto*), continue to utilise this fuelling process, as do some older Russian SLBMs, including the R29RMU2 *Layner* (RS-SS-N-23 *Skiff*). Russia's more recent SLBM, the RSM-56 *Bulava* (SS-N-32), however, utilises solid fuel. This indicates that the Russian Navy's use of ampoulised liquid-fuel missiles might be coming to an end once the Navy's older systems are retired.

Regarding solid-fuel systems, efforts to develop new oxidisers, such as ammonium dinitramide (ADN), are ongoing. However, there are significant technical challenges associated with the ADN's hygroscopicity, its problematic storage and its incompatibility with commonly used binding agents.[26]

Gliding Toward a Missile Evolution or Revolution?

Despite the widespread proliferation of ballistic missiles at the lower end of the range spectrum, there has been significant concern about the destabilising implications and increased threat posed by some so-called 'novel' missile technologies, such as HGVs.[27] This concern is prudent: the manoeuvrability of HGVs may create escalation risks owing to their target ambiguity. HGVs may also be difficult to track by space-based sensors beyond the boost phase of flight due to their low infrared signatures, possibly creating incentives to pre-emptively use them in a crisis.[28] The short time to target of HGVs also compresses defenders' reaction times, which could lead to a miscalculation in a crisis. Some potential operators have also said that these systems would be used to strike 'high-value, time-sensitive targets', which could undermine crisis stability.[29]

Whether HGVs are a revolutionary new kind of threat to stability or a further evolutionary development of ballistic-missile technology is debatable. Multiple existing types of ballistic missiles, including MaRVs, multiple independently targetable re-entry vehicles (MIRVs), aero-ballistic SRBMs and air-launched ballistic missiles, as well as air-breathing systems such as land-attack cruise missiles (LACMs), already create target ambiguity to varying degrees because of their manoeuvrability or ability to spread warheads from a single missile across large distances by using a post-boost vehicle.[30] Many types of these systems also already travel at very high speeds that reduce reaction times. Indeed, some analysts have modelled the performance of HGVs against ballistic missiles flying depressed trajectories and have concluded that gliders will travel more slowly to their targets than 'traditional' systems.[31] Despite this divergence, several countries have expressed concern about the stability implications of these systems.[32]

Nonetheless, given the significant financial and technical challenges associated with the development of HGVs, it is likely that proliferation in the near term will be limited to a handful of technologically advanced and wealthy states. The US is yet to deploy an HGV, although the estimated price of US$50–100 million per weapon will likely have ramifications for the number procured, even if costs can be reduced as US officials expect.[33] China and Russia already operate HGVs, but the number of operational systems both countries have is small. Although Russia has deployed an HGV known as *Avangard* (RS-SS-19 *Stiletto* Mod 4) since 2019, its possession is limited to six units, which is slated to increase by only two per year.[34] It is likely China operates at least one brigade of its medium-range HGV, the DF-17 (CH-SS-22), but whether the People's Liberation Army Rocket Force (PLARF) intends to replace its large MRBM force with the DF-17 or only complement it is not clear.[35] Although the cost of China's programme is unknown, considering that it is thought to be the world's largest and best funded, Beijing's outlays may be even higher than the nearly US$15 billion the US will have spent between 2015 and 2024 on hypersonic development.[36] High costs might therefore prevent some states that have expressed an interest in acquiring high-speed weapons from realising their ambitions, although collaborative development could provide a more affordable and achievable means of procurement.[37] Considering the price tag of some HGVs and the probable small numbers that will be deployed, operators may be more likely to use these systems as niche options for destroying a limited number of very high-value targets, such as missile defences, rather than use them in a conventional war-fighting role like how 'traditional' ballistic missiles are used.

BALLISTIC MISSILE MANOEUVRABILITY
MaRVs, such as the *Pershing* II, include many of the same features present in today's HGVs. CREDIT: HUM Images/Universal Images Group/Getty Images.

HEAT TESTING
A missile nose cone is tested with intense heat, March 1958. Advanced composites and materials are needed to withstand high-speed flows at Mach 5+ speeds. CREDIT: Don Cravens/The Chronicle Collection/Getty Images.

Beyond costs, HGVs present developers with multiple materials-science and aerodynamics challenges. In high-speed flows, surfaces are heated by compression and friction. Composites therefore need to be designed to provide the glider's airframe with sufficient thermal protection from the intense heat that is generated at these speeds.[38] Seekers also require protection from heat sources, otherwise excessive thermal loading will saturate the sensor and reduce the glider's capability to identify and accurately strike its target.[39] Although the aerodynamics of conical ICBM re-entry vehicles and MaRVs are well understood, there is less knowledge of the aerodynamic properties and control surfaces of wedge-shaped glider surfaces.[40]

Guidance presents another challenge, as in excess of Mach 5 speeds, guidance methods used in ballistic missiles become problematic, as electro-optical and radio frequency (RF) seekers may struggle to operate through plasma sheaths.[41] Moreover, sensors can become overwhelmed by intense heat and severe airframe vibrations caused by high g-force turns at hypersonic speeds. As rocket boosters are needed to launch the glider, developers will also need to develop an efficient, reliable and cost-effective means of primary propulsion, which requires a sovereign launch capability.

LACMs: When Evolution Is More than Enough

Revolution and transformation are much overused words in the military realm, not least of all when it comes to very-high-speed cruise missiles. Cruise missiles alone, irrespective of their speed regime, have been neither revolutionary nor transformational, but this does nothing to negate their considerable military utility or their possible implications regarding arms control.

The evolution of cruise missiles has often been slow, punctuated by technical progress, and sometimes a solution in search of a problem.[42] Nor has the technology always found early favour with the armed services that eventually introduced them into their inventory and embraced their capabilities.[43] Three decades on from the first operational use of a precision LACM, however, a new wave of development and adoption may be approaching.[44]

The emergence of enabling technologies that offer a path to hypersonic cruise missiles has drawn much attention and commentary. The other end of the speed gradient has attracted less attention, but developments there also are worthy of note. Near 1,000-km-range cruise missiles have been made available to an NSA (Ansarullah) less than three decades after only one nation (the US) had a conventional LACM in its inventory.[45]

Coming to Terms

Like their ballistic counterparts, technical developments continue to outstrip the lexicon, leaving room for misunderstanding, misidentification or misrepresentation. All three are of importance for the arms-control arena if, despite present travails, there remains a collective impetus to try to secure further agreements or at least bolster current regimes.

In its broadest and perhaps least helpful definition, a cruise missile is a weapon that is flown within the atmosphere, is guided, is powered and relies on some form of aerodynamic surface, most commonly a wing, to generate lift. Such a limited description encompasses many air-launched weapons and a smaller, but still significant, number of surface-launched types. Range and speed regimes, however, are useful in providing a more practical definition. There is also an implicit assumption in the term 'cruise missile' that the weapon has a significant range beyond that of a direct-fire or tactical-range missile. In the case of an LACM, there is no generally agreed range categorisation as there is with ballistic missiles. Cruise missiles, however, would span the CRBM, SRBM, MRBM and IRBM categories, with one current developmental system, Russia's nuclear-powered *Burevestnik* (RS-SSC-X-9 *Skyfall*) – should it ever work – having an endurance that from ground launch would place it well into the intercontinental bracket.[46]

There are three generally accepted cruise-missile speed regimes within the atmosphere: subsonic (less than Mach 1), supersonic (between Mach 1 and 5) and hypersonic (Mach 5+). A point well made by analysts is that hypersonic is an adjective, not a noun, meaning that it is an attribute rather than an object.[47] Almost all LACMs now fielded are subsonic; China's CJ-100 (CH-SSC-13 *Splinter*) and the land-attack version of India's *Brahmos* (a derivative of the NPO Mashinostroyenia 3M55 *Onix* (RS-SS-N-26 *Strobile*) anti-ship missile), are the only two dedicated LACMs now in service where nearly all the flight is at supersonic speed. As yet, no Mach 5+ LACM is known to have entered service.

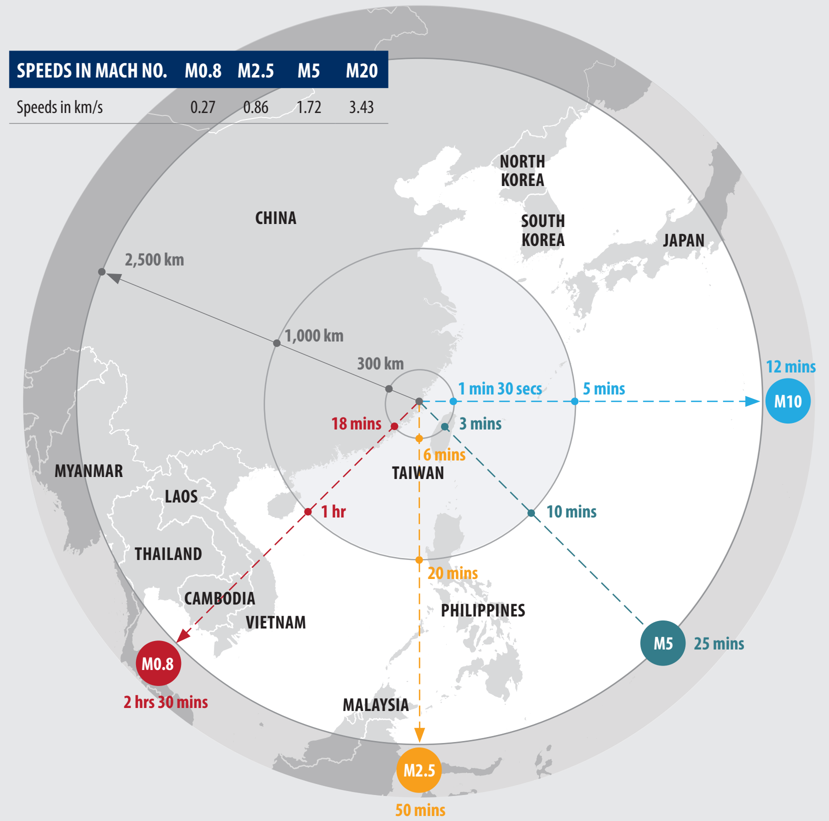
Distance Over Time

Advanced LACMs can now be used against targets at distances in the order of 2,000 km and greater, with inaccuracies measured in no more than a few metres. Until the 1980s, what were broadly described as 'strategic' cruise missiles were restricted to the nuclear-strike role. They were limited to the destructive power of a nuclear warhead because the accuracy required for the use of a conventional warhead to generate the desired military effect was lacking. The US Boeing AGM-86B Air-Launched Cruise Missile entered service in late 1982 and was described in unclassified literature as having a CEP of 100 m, with the missile fitted with a 200-kiloton warhead.[48] The Soviet Union's *Novator* 3M10 (RS-SS-N-21 *Sampson*) submarine-launched cruise missile, which entered service from the mid-1980s, at the time was estimated by the US intelligence community to have a CEP of 100 m.[49]

While more than a magnitude in accuracy poorer than long-range cruise missiles now in service, the likes of the AGM-86B and the 3M10 were, in turn, a step change in performance from previous efforts to develop and field long-range LACMs. In the 1950s US and Soviet designers had worked on a variety of cruise missile programmes for nuclear missions, most of which fell woefully short of their goals and, in turn, were to fall out of favour, with ballistic missiles becoming the preferred choice to fulfil nuclear-deterrence roles.[50]

In nuclear theology, the limitations in accuracy of the 1950s cruise systems meant they would primarily have been of use in counter-value strikes. By the latter part of the 1970s and into the 1980s it was apparent that developments in guidance technology would likely provide the option of using LACMs with a comparatively low-yield nuclear warhead in the counterforce role.[51] US developments concerned the Soviet military hierarchy and were a feature of arms-control discussions between Moscow and Washington at the time, even as the Soviets worked on their own submarine, ground and air-launched LACM projects.[52]

Map 1.1: **Subsonic to hypersonic cruise-missile flight times**



			HYPERSONIC	
300 KM				
	SUBSONIC (M0.8)	SUPERSONIC (M2.5)	LOW (M5)	HIGH (M10)
	18 mins	6 mins	3 mins	1 min 30 secs
1,000 KM				
	SUBSONIC (M0.8)	SUPERSONIC (M2.5)	LOW (M5)	HIGH (M10)
	1 hr	20 mins	10 mins	5 mins
2,500 KM				
	SUBSONIC (M0.8)	SUPERSONIC (M2.5)	LOW (M5)	HIGH (M10)
	2 hrs 30 mins	50 mins	25 mins	12 mins

Source: 'Trends in missile technologies', IISS blog

HYPERSONIC MISSILES
Mach 5+ air-breathing designs present operators with opportunities, but their development is challenging. CREDIT: Robert Nickelsberg/Getty Images News/Getty Images.

'Progress' on a Broad Front

The conventionally armed LACM was a 'novel' weapon in 1991 when the US debuted the *Tomahawk* Land Attack Missile (TLAM) and the AGM-86C Conventional Air Launched Cruise Missile (CALCM) in the Iraq War.[53] Their use was the culmination of weapons developments begun in the 1970s, developments enabled by progress within several technologies, particularly midcourse and terminal guidance and propulsion. The AGM-86C, unlike TLAM-C/D, benefited from being fitted with satellite navigation.[54] The TLAM Block II used terrain contour matching (TERCOM) and digital scene matching (DSMAC) but lacked the satellite navigation of the AGM-86C, an absence remedied in the aftermath of the war with the TLAM Block III.[55]

Novel in 1991, the subsonic conventionally armed LACM is now near ubiquitous in the inventories not only of states but also of at least one NSA (Ansarullah). As of mid-2022, 24 countries were known to field LACMs, with several others pursuing national development or acquisition. Iran, meanwhile, had supplied the Project 351/*Quds* to Ansarullah forces in the Yemeni civil war, making it the first known NSA to possess an LACM.[56]

CONVENTIONAL LACM
Launch of a US BGM-109 *Tomahawk* cruise missile (originally a novel LACM due to its conventional warhead), 1991. CREDIT: Historical/Corbis Historical/Getty Images.

The technical goals that enabled the US adoption of the conventional LACM in the 1980s, accuracy and survivability, in the latter case of the missile and the launch platform, are once again broad developmental aims for the generation of weapons now in test or at the design stage. The current environment differs notably, however, in that high speed is again a design driver. Several nations, not just the US, are in pursuit of this technology and Washington no longer has a marked lead in development.[57]

Very-high-speed in-atmosphere flight has long been attractive to weapons developers, but until recently the air-breathing propulsion to support sustained Mach 5+ flight remained in the experimental realm. Ramjet designs have been used to provide a few weapons designs with speeds of around Mach 4 but offer the potential to operate in the low-hypersonic envelope of Mach 5–6 and perhaps a little beyond. Air-breathing atmospheric flight above this speed requires a scramjet.

How Fast Is Fast Enough?

Speed is a fundamental component of military activity, encapsulated by John Boyd's much cited Observe–Orient–Decide–Act loop.[58] Getting inside an opponent's decision cycle, whether tactical or strategic, is advantageous. In the realm of physical attack, the speed of the targeting cycle may determine whether an engagement is successful or not. If too slow, then the intended target may have been relocated, or been able to already carry out a successful attack. Time of flight of the weapon from launch to impact can be a key factor in determining the outcome of an engagement, but this needs to be supported by a targeting cycle able to exploit the speed of the weapon. In the contest between ground-based air defence and air platforms, the former has turned increasingly to mobility, or at least being relocatable, to improve survivability. Shortening the time between detection and arriving on target increases the probability of a successful engagement, but it is far from the only determinant.

Very-high-speed in-atmosphere flight also confronts a defender with detection and engagement challenges, again making such a capability attractive from the offensive perspective.[59] Ground-based air-surveillance and air-defence radar has not in the past been focused on the altitude regimes where HGVs or hypersonic cruise missiles would be flown. Satellite-based detection systems, meanwhile, have tended to be designed to detect the launch bloom of an ICBM, rather than the far smaller infrared signature of an HGV or hypersonic cruise missile.

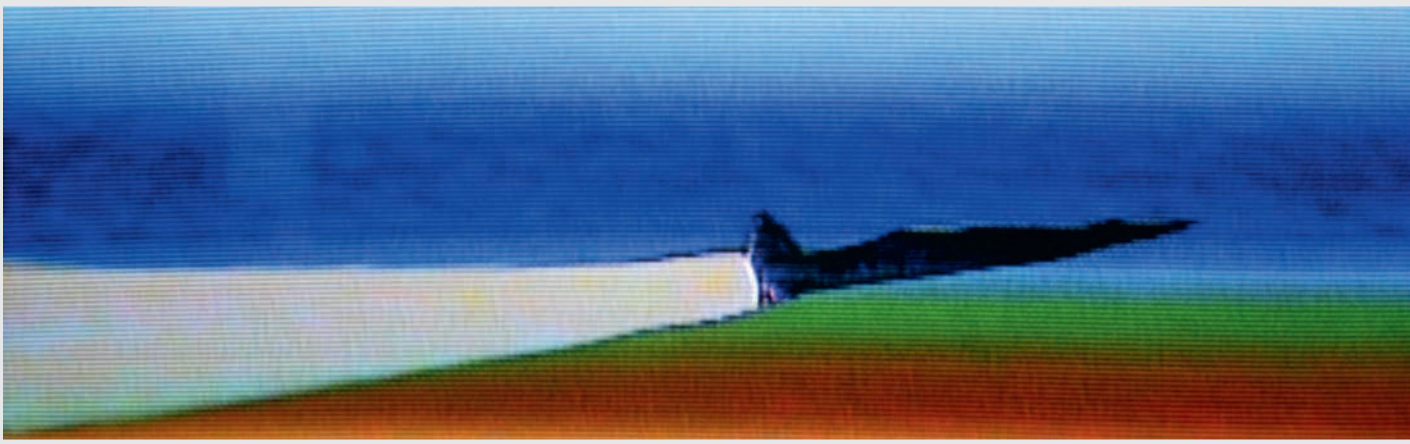
Speed Trap

Irrespective of all the attractions of very-high-speed cruise missiles, until recently the collective technical challenges have been near insurmountable in considering the development of an operationally useful missile system. Atmospheric flight at speeds in excess of Mach 5 brings with it an array of design challenges with regard to the aerodynamic and thermal environments and the technologies required to address these.[60] In the case of hypersonic cruise missiles there is the further issue of propulsion. While the performance of ramjets is well understood and can provide for speeds at the very low end of the hypersonic envelope, scramjets are far less mature.

The advantage of air-breathing propulsion is that it saves weight compared with a ballistic missile. Atmospheric oxygen is utilised rather than carrying an equivalent on board within the missile body.[61] Ramjets are mechanically simple, relying on free-stream atmosphere, rather than the use of a compressor, for a build-up of pressure.[62] This, however, requires that the missile velocity already be great enough for the free-stream flow to support ramjet ignition and the generation of the required level of thrust: the missile body generally needs to be at Mach 2–3 to allow transition to the ramjet sustainer. A solid-booster motor is the most common method of accelerating the missile to the required speed.

The use of a ramjet for low-hypersonic-speed flight brings with it its own problems. In a ramjet the airflow must be slowed to subsonic speed for combustion. In turn, this places thermal stresses on the intake, combustor and nozzle structures as the air is slowed with the resulting increase in temperature.[63] At the upper end of a ramjet's speed regime there is also a notable reduction in efficiency.[64] A balanced and integrated design, however, should allow for efficient flight in the Mach 5–6 regime, but not much beyond this.

An alternative is to avoid slowing the free stream to subsonic speed, and instead to sustain combustion in a supersonic airflow, hence supersonic combustion ramjet, or scramjet, for short. Scramjets are not limited to the same speeds as ramjets beyond Mach 5. An obvious technical demand in comparison to a ramjet is the need to sustain combustion in a supersonic airflow, and the very short period in which gases pass through the combustion section.[65] Despite decades of interest in very-high-speed flight and the application of scramjet engines by 2010, the longest flight time of scramjet-powered missile-like design was just 200 seconds.[66] By 2022 this figure had only progressed to around 320 seconds, with the flight of the Lockheed



SCRAMJETS
Sustaining combustion at supersonic airflow is difficult due to the very short period in which airflow passes through the combustion section. CREDIT: Robyn Beck/AFP/Getty Images.

SLOW AND VERY LOW OBSERVABLE
MBDA presents its 'Future Low Observable Subsonic Cruise Missile' concept at the DSEI arms fair, 10 September 2019. CREDIT: Leon Neal/Getty Images News/Getty Images.

Martin design for the USAF's Hypersonic Air-Breathing Weapon Concept (HAWC).[67] China's scramjet-powered *Starry Sky* II (*Xingkong* II) was reportedly test flown for 400 seconds, but how much of this was with the scramjet in operation is unclear.[68]

While there is much that remains uncertain, and additionally much that remains classified, what is apparent is that several countries are now pursuing research and development into Mach 5+ cruise missiles. Australia, China, France, India, Japan, Russia, South Korea, the UK and the US all have very-high-speed cruise-missile research and development programmes under way, with varying degrees of investment and progress. It is possible – if not likely – that at least some of these nations will be able to field Mach 5+ cruise missiles before the end of the decade, with others to follow in the 2030s.

A further propulsion option is a combined-cycle engine which brings together different types of propulsion. Rocket-based combined-cycle engines are now being explored using either a ramjet or scramjet in conjunction with a rocket for high Mach-number flights. Such an approach, however, is likely to be favoured for reusable high-speed air vehicles, in no small part because of the cost.

Testing Times

As previously indicated, the development of very-high-speed cruise missiles presents a range of technological challenges. The missile airframe and the propulsion system must be integrated to a far greater degree than subsonic and even supersonic cruise-missile designs, with the level of dependency between the airframe and the propulsion in ensuring missile performance far higher.[69] In a hypersonic cruise-missile design, even a small modification to the airframe – which in a subsonic or supersonic design would not affect performance – can be critical given the loads experienced in flight.

Thermal loads in the hypersonic-flight regime require that the design be able to operate at temperatures ranging from 1,000–2,300°C-plus, depending on that part's location within the vehicle body.[70] As a reference point, titanium – a high-strength metal oxide used in aircraft, spacecraft and missile designs – melts at just over 1,650°C.[71] The 'lower' temperatures are the result of aerodynamic-friction heating, with the higher temperatures arising in the combustion chamber and outlet. Active cooling, using the fuel as a heat sink, is one approach to dealing with such high temperatures; another is to rely on radiative cooling, where one property of the material used is a high convection rate.[72] A mix of techniques may be used to deal with temperature issues in different areas of the airframe.

While computer modelling and simulation have increasingly been relied upon to reduce the amount of real-world testing required of flight vehicles, such are the demands of the hypersonic-flight regime that these cannot be relied upon to the same extent. Nor do wind tunnels fully address the gap, though they do allow the required replication of elements of a very-high-speed environment, if for non-representative times and only subscale.[73] As with everything else associated with hypersonic cruise-missile development and technology, the ground-test infrastructure is expensive. As such, the scale and focus of the Chinese effort can in part be gauged by the substantial investment in and development of high-speed wind tunnels in Beijing and Mianyang.[74] The latter is home to the China Aerodynamics Research and Development Centre, which includes the Air-breathing Hypersonic Research Centre and the Scramjet Science and Technology Laboratory. The Mianyang site has been developed just over the past decade. In Beijing the JF12 Mach 5–9 wind tunnel entered use in 2012, while the JF22 wind tunnel, capable of simulating up to Mach 30, is due to open in 2022.[75]

Materials Issues

Along with the basic airframe, sensor apertures and antennas also drive the development of suitable high-temperature materials. The more commonly used materials for imaging infrared (IIR) and RF domes are not suitable for Mach 5+ flight.[76] Ceramic matrix composites are now seen as a promising material to produce an RF radome capable of managing the thermal shock generated by hypersonic flight.[77] Hypersonic flight may also generate a plasma field because of shockwave behaviour at very high speeds, though this is normally associated with Mach 10 and above. The interaction between plasma and RF antennas can reduce the performance of the latter, as demonstrated by the well-known communications blackout experienced by crewed space vehicles during re-entry. There remain questions also as to whether plasma fields would interfere with the use of satellite navigation or datalink updates.[78]

For IIR and electro-optical sensors the issue is arguably greater. As well as the effect of the shockwave refracting light, an optical window exposed to the airflow is subject to considerable heating. Active cooling, combined with only being exposed to the airflow in the final stages of an engagement, is one means of managing the thermal demands.[79]

Slow and Very Low Observable

While there has understandably been a focus on hypersonic cruise missiles and the emerging technologies that support such developments, advances in subsonic and, to a lesser extent, supersonic cruise missiles also continue. At Mach 5+, speed alone confers a considerable degree of survivability, but in the subsonic realm this clearly is not the case. Instead, passive and active signature-management techniques to further reduce a missile's radar cross section and to manage infrared emissions continue to be pursued. Subsonic designs are now being developed with improved low-observable radar signatures to further challenge defences.[80] There also remains interest in greater stand-off ranges to improve launch-platform survivability. Russia is continuing to work on the *Izdeliye* 506, also known as Kh-BD (BD meaning long range), in what may be a further development of the *Raduga* Kh-101/Kh-102 (RS-AS-23a/b *Kodiak*) air-launched subsonic cruise missile already in service.[81] With the nuclear-powered *Burevestnik*, Moscow is aiming to develop an intercontinental-range subsonic cruise missile that it can ground launch against an adversary from within Russia. The US, meanwhile, continues to work on a successor to its AGM-86B subsonic cruise missile. Raytheon was awarded an engineering and manufacturing development contract for the Long-Range Standoff (LRSO) in July 2021.[82] The LRSO in the USAF inventory will be known as the AGM-181. As of the third quarter of 2022, even the basics of the missile remained classified. The USAF has said only that it will not be a hypersonic cruise missile and that, thus far, it is planned to be nuclear-only, though this could change.[83]

The long-range subsonic cruise missile indigenous-capability club will likely only grow larger. Turkey, for example, is reportedly working on a 1,000-km-range-class missile known as *Gezgin*.[84] Iran, meanwhile, is also continuing to develop at least two families of cruise missiles, the project known by Iran as 351, and the *Meshkat*/*Soumar* range based on the Soviet-era *Raduga* Kh-55 (RS-AS-15 *Kent*).[85] It is the former, rather than the latter, that so far has proved the more worrisome regionally since Tehran has provided it to Ansarullah in Yemen (where it is referred to as the *Quds*). The 351 has been used several times by Ansarullah for attacks on Saudi Arabia, likely often with Iranian involvement or support.

Hyper-activity and Arms Control

A hypersonic cruise missile is a weapon that can be used for strategic effect, but it is not a strategic weapon per se. It is the intent, rather than the weapon, that is strategic.[86] HGVs and hypersonic cruise missiles have, unsurprisingly, been a source of concern to the arms-control community, although there is no unanimity as to whether they are inherently destabilising, and if so, to what extent. The debate is further complicated by the lack of clarity around the intentions of some of the countries pursuing hypersonic cruise missiles as to whether they will be conventional only, or designed from the outset to be able to be fitted with either a conventional or a nuclear payload.

They also pose questions for remaining arms-control treaties and regimes. The US–Russia New START does not directly

TEST SECTION OF A SUPERSONIC WIND TUNNEL
Wind tunnels offer a practical but expensive means to test aerodynamics. CREDIT: Greg Kahn (GRAIN)/The Washington Post/Getty Images.

address cruise systems, but rather refers to the carrier – in this case, bomber aircraft.[87] The multilateral MTCR range and payload Category I threshold is also arguably flawed when it comes to dealing with hypersonic cruise-missile technology.[88] While it is likely that any hypersonic cruise missile developed will exceed the 300-km-range threshold, it is also likely that its payload (warhead) will not exceed 500 kilograms. As such, in terms of export this class of weapon would be a Category II item, where national discretion would apply.

Very-high-speed cruise missiles, however, are unlikely to be made available for export, or to be able to be developed nationally, in as widespread a manner as subsonic cruise missiles, certainly in the near to medium term. Regarding the prospect for national development, this is in part due to the entry-level needs of the required technology base, the high costs of developing the requisite technology-building blocks and the costs of the ground-test infrastructure, as outlined above. Given that there are already concerns surrounding their capabilities, there is also likely to be greater reticence to export such systems on the part of developing countries, though there may well be exceptions. This, however, is not a reason for complacency. Furthermore, at the other end of the speed regime, the provision of subsonic LACMs to at least one NSA is a concern. Their successful use by Ansarullah may have served only to further whet the appetite of other non-state groups for such a capability.

Notes

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Chinese, Russian and US Arms Control

CHAPTER TWO

Classic arms-control theory posits that successful agreements necessitate that parties share a common conception of the requirements for strategic stability. Historically this has certainly been the case. Ever since the 1922 Washington Naval Treaty, the first arms-control agreement that limited the strategic weapons of the time (i.e., dreadnought-class battleships), through to today's generation of strategic nuclear-arms agreements between the United States and Russia, the parties to such treaties have needed some agreement on the military-technical basis for strategic stability in order to make any significant headway.[1]

Yet while a shared conception of the requirements for a stable military balance is necessary for successful arms control, it is not sufficient in itself. If it were, then we would not be facing the collapse of the current arms-control architecture. A basic understanding among the three major powers – China, Russia and the US – likely exists. For instance, all three have fielded systems that indicate a shared understanding regarding the importance of retaining a secure second-strike posture as the bedrock of strategic stability. Beijing, Moscow and Washington all behave in ways that suggest that they almost certainly share a common conception of those exigencies.

New missile technologies – such as increasingly fast and accurate missiles with atypical trajectories – may threaten strategic stability, but they have not fundamentally overturned settled understandings of how deterrence works. The emergence of hypersonic cruise missiles, which have shorter flight times to target than existing air-breathing systems, and possibly some shorter-range ballistic missiles, as well as hypersonic glide vehicles (HGVs), with significant targeting ambiguity during flight, existing high-precision conventional weapons capable of counterforce missions, and new generations of missile defences could undermine secure second-strike forces, increasing crisis instability and serving also to fuel weapons-technology races. The mechanisms by which they do so, however, are readily understandable within established analytical frameworks. Given this, it should be possible to design arms-control agreements that could limit these systems. Governmental and non-governmental organisations specialising in arms control have developed a multitude of proposals that could help limit the adoption and spread of these technologies.[2]

Key takeaways

ROOTS OF COMPETITION

The erosion of the global arms-control architecture is not military-technical, but political and economic. Neither the US nor China is near the limit of its economic capacity to race against the other.

DOMESTIC RESERVATIONS

It seems highly unlikely that the US Congress will revive its historical role of compelling the executive branch to take significant additional steps towards additional arms control arms-control agreement beyond urging efforts for a new arms-control agreement limiting non-strategic nuclear weapons.

RUSSIA, UKRAINE AND THE APPETITE FOR ARMS CONTROL

Russia could prioritise its nuclear arsenal to strengthen its deterrence strategy during a period where its conventional forces are depleted and have suffered a considerable blow to their prestige.

IMPLICATIONS OF NEW MISSILE TECHNOLOGY

New missile technologies may present challenges to strategic stability, but they do not fundamentally overturn settled theories of deterrence and strategic stability.

DIFFICULT FUTURE COOPERATION

While China, Russia and the US share a broad and common understanding regarding the military-technical requirements for strategic stability, hardly any of the other preconditions that have incentivised arms-control accords in the past appear to be present.

The problems that beset today's crumbling arms-control architecture are not military-technical, but political and economic. Over the past century, certain incentives have encouraged the major powers to successfully conclude negotiations to limit and reduce their armaments. In the US, the world's largest economy throughout this period, domestic incentives to limit armaments have primarily stemmed from Congress, which has periodically constrained the Executive's ability to leverage America's considerable economic resources to military ends. For the United States' rivals, the key domestic incentive has primarily been resource-based, in order to ease the strains of being involved in an arms race with the world's foremost economic superpower.

Internationally, arms-control agreements between the major powers have been possible when they are underpinned by a common understanding of the basic principles of global order. In practice, this has meant two things. Firstly, the major powers have been able to come to a broad understanding, if not consensus, on their respective statuses. That does not necessarily mean equality; the Washington Naval Treaty explicitly encoded unequal statuses for its five participants, although during the Cold War most arms-control agreements aimed towards equality of outcome (if not obligations). Secondly, successful arms control has required that major powers are able to manage key regional questions that lie at the heart of their rivalry. For the key players in previous eras, such as the US, the British Empire and Japan during the Washington Naval Conference, that meant coming to an understanding over their respective spheres of influence in the Asia-Pacific. During the Cold War, it meant the establishment of a broad diplomatic understanding that the division of Europe would not be altered by force. Neither side put full faith in the subsequent accords (i.e., the Helsinki Final Act) and both continued to prepare for the worst, but the political agreements that were signed in parallel with arms-control agreements provided a level of assurance that the parties understood the futility of seeking to revise these divisions through military action.

These domestic and international conditions are hardly present today. Neither the US nor China is near the limits of its economic capacity to race against the other, and Russia's current economic strains have yet to translate into any willingness to close the significant gaps between its position and that of the US regarding new arms-control measures. The powers are fundamentally split on the question of their relative status and over geopolitical disputes in Europe and the Asia-Pacific – that is, Russia's and China's revisionism and the US seeking to maintain the status quo. Domestic and international forces point away from arms control and towards increased incentives for greater competition between the major powers, largely unconstrained by domestic political or economic pressures and in pursuit of these fundamentally conflicting geopolitical aims. Unless these conditions change before the 2026 expiry of the US–Russia New Strategic Arms Reduction Treaty (START), then the current era of major-power nuclear-arms control that began in 1972 is over.

The Military-Technical Basis for Arms Control

A shared conceptual framework among participating states regarding the military-technical requirements for a stable military balance is a prerequisite for successful arms control. The conceptual framework for arms control governing existing offensive and defensive missile systems is highly developed and has deep roots in US, European and Russian thought. Moreover, it is possible to apply established arms-control principles to emerging missile technologies and identify their destabilising characteristics. From the evidence available, it seems that the Chinese government understands and shares this basic framework.[3]

Given these shared foundations regarding the military-technical requirements for stability, there are a number of arms-control agreements that may be feasible.

Shared Military-Technical Theory of Stability

All arms-control agreements rest on some shared understanding of the requirements for a stable strategic balance, even if the contracting powers diverge from that ideal in practice by continuing to compete in areas not covered by the agreement. Indeed, a shared understanding of stability is necessary to make those divergences from the prescriptions of strategic stability militarily and politically meaningful to both sides. Without a mutual understanding of the military-technical requirements for a stable balance, the threat that new systems pose to that balance – and therefore the military-technical advantage that they hold for the side possessing them – is less readily understandable by the parties to an existing agreement.

Under the Washington Naval Treaty, the US, the British Empire, France, Italy and Japan were limited in capital-ship tonnage to a ratio of 5:5:3:1.75:1.75 respectively. This ratio reflected settled understandings regarding the primacy of dreadnought-era battleships as the key metric of naval power, but also the limitations of this technology, such as its reliance on established bases with their stocks of fuel and repair facilities and vulnerability to new innovations, notably submarines armed with underwater torpedoes, mines and the nascent threat of naval airpower. All of this meant that at a certain distance from its own bases, an attacking fleet would no longer be able prevail against a well-armed adversary that enjoyed the advantages of better access to fuel, repairs and support from auxiliary units. Too far from its supporting bases, an attacking force would lose the 'decisive battle' between the belligerents' major battle-fleets hypothesised by naval theorists of the period, and thus lose command of the sea and therefore the war.[4] These characteristics were combined to create a naval balance whereby the three major powers – Britain, Japan and the US – were able to maintain sea control in their own spheres of influence but were left with insufficient battleship tonnage to challenge the other powers' dominance in their own respective spheres.[5] Thus a common understanding of the naval capabilities of the time formed the necessary military-technical basis for arms control between the leading naval powers of the day.

In the nuclear era, superpower arms control can be seen as the imperfect search for strategic stability based on secure second-strike forces and mutual vulnerability to retaliation. Expounded by Thomas Schelling and Morton Halperin in 1961 in *Strategy and Arms Control*, this overarching goal has two key sub-objectives: crisis stability (low incentive to use nuclear weapons first during a period of high tension) and arms-race stability (low incentive to engage in competitive acquisition of armaments during peacetime).[6] In the standard telling of arms-control history, the two superpowers came together to embed these principles in a series of accords, starting with the Strategic Arms Limitation Talks (SALT), which resulted in the signing of the Anti-Ballistic Missile (ABM) Treaty, which banned the deployment of nationwide missile defences by limiting both powers to two missile-defence sites (later reduced to one site) each, and the Interim Agreement on Offensive Forces, which froze the build-up in the superpowers' strategic offensive missile launchers. It was also reflected in other accords, including the 1972 US–Soviet Incidents at Sea Agreement (INCSEA), which created a robust risk-reduction tool for hazardous air and sea encounters. This trend continued through the Strategic Arms Reduction Treaty (START) and related follow-on negotiations that supported strategic stability and secured deep cuts in the strategic nuclear inventories of both sides, including the 2010 New START agreement that remains in force today.

EARLY ARMS CONTROL
France, Italy, Japan, the UK and the US agree to limit the size of their respective navies to avoid a costly arms race, 1923. CREDIT: Topical Press Agency/Stringer/Getty Images

The extent to which the two sides in fact followed the axioms of strategic stability in their arms-control negotiations has been a subject of debate, both at the time and in recent years. Significantly, the 1972 Interim Agreement did not limit multiple independently targetable re-entry vehicles (MIRVs), arguably the most destabilising technology of the era.[7] By multiplying the offensive potential of each individual missile, through both the increase in the number of warheads on each individual missile and increased warhead accuracy, MIRVs held open the possibility of a damage-limiting first strike against an adversary's strategic nuclear forces, thereby exacerbating both arms-race and crisis instability. The unratified – though informally observed – SALT II agreement, signed in 1979, included some restrictions on MIRVs through a series of numerical and testing limits on MIRVed missiles, but at very high levels that meant the counterforce capabilities of each side remained largely unconstrained.[8] START I, agreed much later, in 1991, accounted for and reduced MIRVed delivery vehicles, but did so in ways that arguably left considerable asymmetries in the first-strike capabilities of the two sides, placing relatively light restrictions on the United States' new generation of counterforce-capable submarine-launched ballistic missiles (SLBMs), the *Trident* D5, and heavy bombers carrying air-launched cruise missiles, while mandating drastic cuts in the Soviet Union's most capable counterforce weapons, notably the heavy R-36M (RS-SS-18 *Satan*) series of intercontinental ballistic missiles (ICBMs).[9]

Thus the history of arms control shows that there have been considerable divergences from the ideal of strategic stability in practice. However, in order for those divergences to have any kind of significance, the two sides must have a shared view of the requirements for stability against which to measure the threat that any such division poses to the achievement of a truly stable relationship. For example, the exclusion of MIRVed systems from an agreement can only be seen as significant if both sides agree that the requirement for invulnerable second-strike forces is fundamental for strategic stability and therefore both understand

SALT I
Soviet premier Leonid Brezhnev and US president Richard Nixon in Moscow for SALT I – the first of multiple successive Soviet/Russian–US accords.
CREDIT: Keystone/Hulton Archive/Stringer/Getty Images

the threat that MIRVs pose to the achievement of this posture. The history of the Cold War shows that, at least by the 1970s, both sides understood the significance of such threats to the security of their second-strike forces and thus had reached a basic shared conception of strategic stability, even if they willingly diverged from that conception in practice by continuing to compete in the development of counterforce systems.[10]

This continued imperative for competition ultimately stemmed from geopolitical factors, specifically the US commitment to maintaining the freedom of its European NATO allies from Soviet armed coercion – and specifically the role of nuclear weapons in countering perceived Soviet conventional advantages. As its quantitative advantage in intercontinental delivery vehicles eroded during the 1960s, Washington became increasingly reliant on its technological edge in areas such as multiple warheads and vast numbers of forward-deployed battlefield nuclear weapons (with 7,000 nuclear weapons assigned to the defence of NATO at its peak) to maintain the credibility of its extended deterrent guarantee, in the eyes of its allies but also importantly in those of domestic audiences and ultimately US policymakers themselves.[11] Consequently, it resisted attempts to limit MIRVs at the first strategic arms-limitation talks, and only became interested in MIRV limits during SALT II once the Soviet Union looked close to acquiring the capability.[12] At the same time, domestic economic and political pressure to reduce US conventional forces in Europe (e.g., the Mansfield Amendment) forced NATO to increasingly rely on forward-deployed nuclear forces, and caused considerable angst – especially in West Germany – about the scale and scope of US–USSR negotiations. This angst began with the US unilateral decision to remove its intermediate-range nuclear missiles from Europe after the Cuban Missile Crisis but gained speed with bilateral negotiations such as the US–Soviet Agreement on the Prevention of Nuclear War, which was suspected by some Allies to be a condominium over the heads of the European powers to safeguard North America and the Soviet Union from the ravages of nuclear warfare. It also gave impetus to NATO to propose talks with the Warsaw Pact to seek balance in conventional forces.

Similarly, the Soviet desire to reduce the credibility of the United States' ability to defend its European allies motivated several of its arms-control positions, including its early insistence that US forward-based systems (FBS) capable of striking the USSR be included in SALT I, SALT II and the brief talks on SALT III, as well as the Mutual and Balanced Force Reduction talks. Once FBS were excluded from bilateral arms control, and the US was seen to be relying upon battlefield nuclear weapons for NATO deterrence, the Soviet Union deployed the RSD-10 *Pioneer* (RS-SS-20 *Saber*) intermediate-range ballistic missiles (IRBMs) – ideally suited to prevent US conventional reinforcement of Europe and thus decouple North America from Europe in war. Once the Soviet Union began deploying the RSD-10 in significant numbers, the US and its NATO allies became newly interested in limitations on theatre-range systems. US and Soviet willingness to limit different types of systems thus ebbed and flowed with the evolution of the military-technical balance between them, but superpower disagreements were fundamentally rooted in this basic variance over the United States' role in the European security system.[13] However, this evolving competition, played out through the introduction of new systems and the evolution of the sides' arms-control positions, only made sense if both sides shared the same overall conception of strategic stability and thus the danger that newly deployed systems posed to each other's nuclear postures.

The conceptual legacy of the Cold War remains in place today in both US and Russian strategic thought. Both sides continue to frame their positions in terms of safeguarding strategic stability and have developed intellectually defensible – if not comprehensive – conceptions of strategic stability that align with and support their arms-control and nuclear-strategic preferences. The US maintains a vision of strategic stability that is focused on the nuclear forces of both sides, arguing that the next steps in the reduction of Washington's and Moscow's nuclear arsenals should include non-strategic nuclear weapons (NSNWs), providing transparency and predictability regarding Russia's extensive NSNW arsenal where there is currently neither.[14] Russia, by contrast, has emphasised what it considers to be new threats facing strategic stability by the development of advanced counterforce-capable conventional weaponry able to reach Russian national territory and forward-deployed missile defences, while maintaining its historic preference to remove US nuclear weapons from Europe, end NATO nuclear sharing and include United Kingdom and French forces in nuclear-arms control. In Moscow's view, it is only through the limiting of emerging systems – as well as other enablers to the US deterrent posture – that a stable situation between the two sides can be achieved.[15] Thus, both the US and Russia identify plausible threats to strategic stability as it has been conceptualised since the early 1960s and offer solutions to those threats.

MIRV
Technological advantages in MIRV technology restrict US interest in pursuing some limitations until the Soviet Union catches up, 1983. CREDIT: US DoD and/or DOE

While China's nuclear-strategic thinking is far less clear, until recently its force posture indicated that it had embraced a dual policy of 'No First Use' supporting 'minimal deterrence' based on a small assured-retaliatory force, of the kind that aligned most closely with the axioms of strategic stability. Beijing did not possess a force large enough to threaten the retaliatory capability of either of its potential nuclear rivals, but it maintained the bare minimum necessary to absorb an attack from either one of them and inflict unacceptable damage in return.[16]

Recent developments, however, indicate that China is moving away from minimal deterrence and adopting a more robust nuclear posture. The appearance of approximately 300 ICBM silos in northern China is the clearest sign that Beijing has expanded its ambitions for its nuclear posture, but it is accompanied also by the expansion of its road-mobile ICBMs, heavy bombers and nuclear-powered ballistic-missile submarine forces, as well as the possible growth in its capacity to produce nuclear warheads.[17] It has also tested a fractional orbital bombardment system (FOBS) that according to US intelligence sources can release some form of submunition.[18] China is expanding its arsenal of dual-capable theatre-range missiles, including the DF-21 (CH-SS-5) series and the hot-swappable DF-26 (CH-SS-18).[19] The final size of the nuclear forces that China aims to acquire is unknown, but the US estimates that Beijing could hold a maximum of 700 nuclear warheads by 2027 and over 1,000 by 2030.[20]

The extent of China's nuclear ambitions is a topic of debate, with some analysts arguing that Beijing is in the process of developing a nuclear force capable of limited first use and counterforce nuclear options in the style of the US and Russia, while others maintain that it is simply attempting to maintain the survivability of its nuclear forces in response to growing US counterforce and missile-defence capabilities.[21] Yet, in expanding the scope of its nuclear ambitions, the observable changes so far in Beijing's nuclear posture do not in themselves indicate that it has a different conception of the requirements of strategic stability than either the US or Russia. Either it is attempting to solidify its existing posture by developing a more survivable force that provides additional options for nuclear retaliation at the strategic and theatre level, or it is moving beyond that baseline to facilitate greater nuclear coercion by providing more destabilising options for nuclear first use at one or both levels. The baseline for judging its posture, assured second strike and the broad conceptual framework within which its nuclear posture fits, is therefore held in common with the US and Russia. Thus, all three powers appear to have the same basic conception of the requirements for strategic stability, which they honour either in the observance or in the breach.

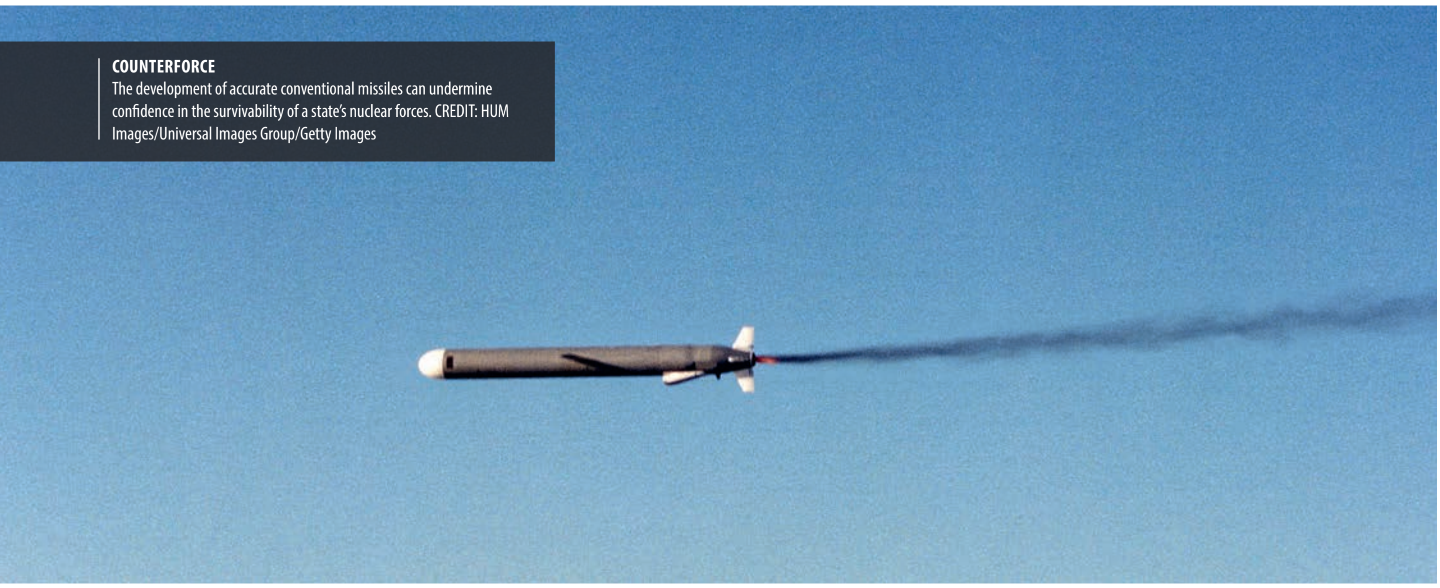
New Missile Technologies and the Possibility of Arms Control

New missile technologies may present challenges to strategic stability, but they do not fundamentally overturn settled theories of deterrence and strategic stability. The core requirements of strategic stability, including the minimisation of states' incentives for first use, primarily through the maintenance of secure second-strike forces, remain the same. As such, new missile technologies' potential effects on stability can be judged and arms-control agreements drawn up to limit their destabilising effects on this basis.

Highly accurate conventionally armed missiles that can be employed in a counterforce role could undermine strategic stability by providing the possessing state with the ability to potentially limit the damage to itself from a nuclear strike, either by complementing existing counterforce attacks using nuclear weapons or, in extreme circumstances, by removing the need to cross the Rubicon of nuclear first use through a conventional-only first strike. While concerns regarding the counterforce potential of such weapons have been around for several decades, improvements in command, control and intelligence, as well as accuracy, make such a threat more plausible today.[22] A perfect counterforce strike on a state's nuclear arsenal remains a highly challenging undertaking. However, by making counterforce options against other states' nuclear forces and their command and control theoretically more effective, conventional counterforce weapons could increase targeted states' fears that they could lose their offensive forces or command-and-control facilities to a first strike. The potentially mistaken belief that they may lose their nuclear forces to conventional or mixed conventional-nuclear counterforce operations could impel states to adopt a launch-on-warning posture, or use their nuclear forces first in a crisis or war. States could also take other measures designed to ensure the continued operation of their nuclear forces after a strike on central command and control, such as delegating the decision over use to lower down the chain of command or to an automated system on the model of the Soviet *Perimitr*, thereby increasing the chance of accidental or unauthorised nuclear use.[23]

Hypersonic cruise and glide weapons also possess potentially destabilising characteristics. Travelling at over Mach 5, the very high speeds of certain types of hypersonic weapons have the potential to decrease states' warning of a nuclear or conventional counterforce or leadership-decapitation attack, reducing the time to consider retaliatory options. This is especially the case for hypersonic cruise missiles, the introduction of which will mark a considerable decrease in time to target when compared to existing cruise missiles. Such weapons could also make counterforce attacks against mobile missile forces more feasible, lowering the survivability of a significant element of many states' nuclear forces. It should be noted that the US has specifically cited the utility of such weapons 'against time-critical, high-value targets' and it is likely that other states see a similar role for such weapons.[24] The in-atmosphere manoeuvrability of hypersonic cruise and glide weapons could also complicate pre-impact assessments of the ultimate target of any attack, leading to worst-case judgements and thus increasing the risk of nuclear use.[25]

The argument about the destabilising effects of strategic missile defences has existed for over 50 years. The first major US public debate over their efficacy took place in 1969, when the Nixon administration's proposed *Safeguard* system faced significant scientific and congressional opposition.[26] Missile defences theoretically make a counterforce first strike more feasible by opening the possibility of protecting the attacker against ragged retaliation from the target of such a strike. They could thus undermine crisis stability by increasing the perceived chances of a



COUNTERFORCE
The development of accurate conventional missiles can undermine confidence in the survivability of a state's nuclear forces. CREDIT: HUM Images/Universal Images Group/Getty Images

successful first strike by the possessor of such a system, as well as the pre-emptive use of nuclear weapons by the potential target of a first-strike counterforce attack. They could also undermine arms-race stability by incentivising non-possessors to augment their offensive forces, including through the acquisition of more missiles and warheads to overwhelm any defensive systems, as well as the development of new weapons that pose additional interception challenges, decreasing the security of the defender and incentivising further arms racing. While the United States' national missile-defence system is neither designed to deal with nor effective against the larger and more sophisticated arsenals of Russia and China, overestimations of its current and projected capabilities nevertheless provide a useful rationale for further development of offensive-weapons technologies in these states. Missile-defence systems based on developing technologies do not fundamentally change this situation.[27]

Emerging missile technologies therefore have the potential to undermine strategic stability, but the means by which they do so can be grasped through established theoretical frameworks that, as the evidence suggests, China, Russia and the US understand and hold broadly in common. Under such conditions, a variety of bilateral or trilateral agreements to reinforce strategic stability at the military-technical level could be possible, both in emerging and in established areas.

Intermediate-Range Missiles

Both the US and Russia have previously expressed concern regarding the dangerous nature of a renewed competition in intermediate-range missile systems in Europe after the demise of the Intermediate-Range Nuclear Forces (INF) Treaty.[28] The mechanisms by which such weapons can impact crisis and arms-race stability are widely known, including their short flight time to target (which could potentially be even shorter with the introduction of hypersonic propulsion technologies). Systems that travel over unpredictable non-ballistic trajectories, such as cruise missiles and HGVs, also introduce significant target ambiguity, leading to possible worst-case scenarios by the target under attack. These factors incentivise use-them-or-lose-them pressures during a war or crisis, particularly if the target state believes such missiles are aimed at their missile forces or command and control. While states may react to this situation by deploying systems that are more easily concealable and more survivable, for example, through the development of mobile launchers, they could also choose to deploy more systems, either to achieve a more survivable force or to increase their first-strike counterforce capabilities. To the target state, the deployment of greater numbers of missiles for survivability or for counterforce is indistinguishable, thereby further fuelling both the arms race and crisis instability.[29] Both Washington and Moscow indicated that they would be willing to discuss means to limit such systems prior to Russia's invasion of Ukraine; however, the viability of such an agreement is now questionable.[30]

Theatre and Tactical Nuclear Weapons

Greater transparency and limits on US and Russian NSNWs are also theoretically possible. Both the US and Russia have pointed to each other's stockpiles of NSNWs in Europe as potentially destabilising.[31] Both sides understand that the other's stockpiles open pathways to, and thus indicate an intent to use, nuclear weapons below the level of a strategic exchange, thereby dramatically raising the risk that a regional conflict in Europe could escalate to a global nuclear war. Given Moscow's lack of clarity regarding the numbers and disposition of its NSNWs, the US has sought, through the Strategic Stability Dialogue (SSD), greater transparency regarding Russia's

9M729
Russia's development of the 9M729 ground-launched cruise missile led to the collapse of the INF Treaty. CREDIT: Vasily Maximov/AFP/Getty Images

stockpile. Although Russia's estimated maximum of 2,000 NSNWs far outweighs the United States' European deployment of approximately 100 B61 nuclear gravity bombs, Moscow has demanded the withdrawal of US NSNWs from Europe before engaging in discussions on its own arsenal.[32] Recent proposals also explore how the disparities between the two sides could be addressed, if they chose to spend the political capital, and while verification would be challenging, that challenge is not insurmountable.[33]

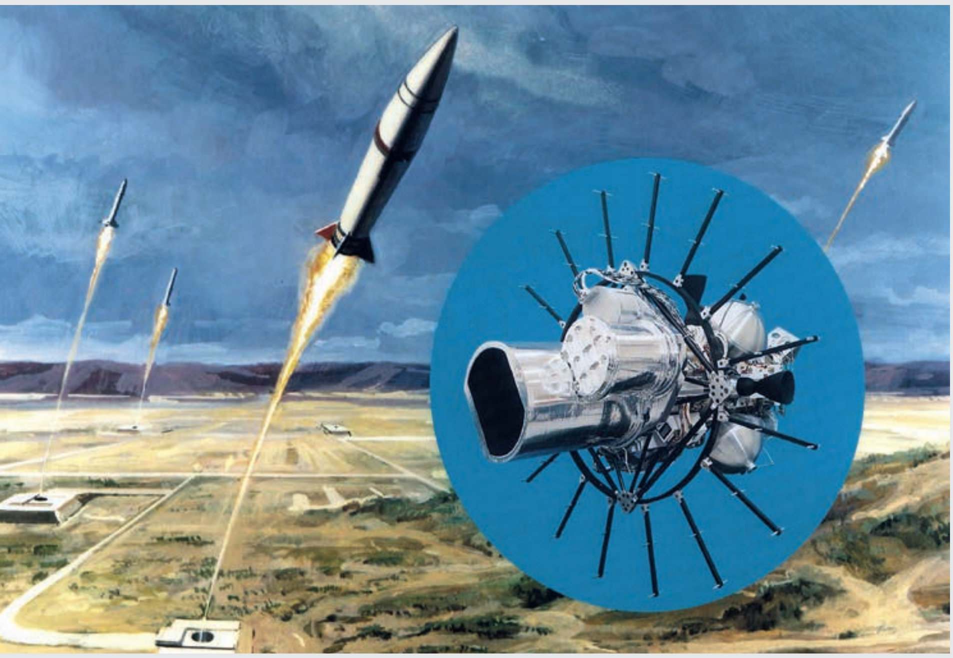
Missile Defences

Limitations on missile defences between the US and Russia, and potentially China, would embed the primacy of retaliatory nuclear forces by outlawing systems that, while falling far short of the capability to reliably neutralise a sophisticated attack, nevertheless help to drive adversaries' anxieties regarding the assured-retaliatory capacity of their nuclear forces, particularly when combined with precision nuclear and conventional counterforce capabilities. The US, the possessor of the most advanced national missile-defence (NMD) system as of the time of writing, has sought to allay such fears by declaring that its system is not directed at the strategic retaliatory forces of either Russia or China.[34] However, this has not been sufficient to prevent the US NMD system from providing a rationale – or excuse – for Russia's development of a series of exotic strategic systems, such as the nuclear-powered and -tipped uninhabited underwater vehicle known as *Poseidon*, as well as an unofficial justification for the modernisation of China's strategic nuclear forces – nor has it restricted Russia and China from pursuing their own advanced missile-defence capabilities.[35] Negotiated limitations on national missile-defence systems could permit 'thin' defences against the smaller and less sophisticated nuclear forces of North Korea, and potentially Iran, while prohibiting 'thick' strategic defences that could be of concern to China, Russia and the US.[36]

Designing a treaty that would outlaw 'thick' defences while allowing 'thin' systems would be a complex task and could proceed through a series of steps:

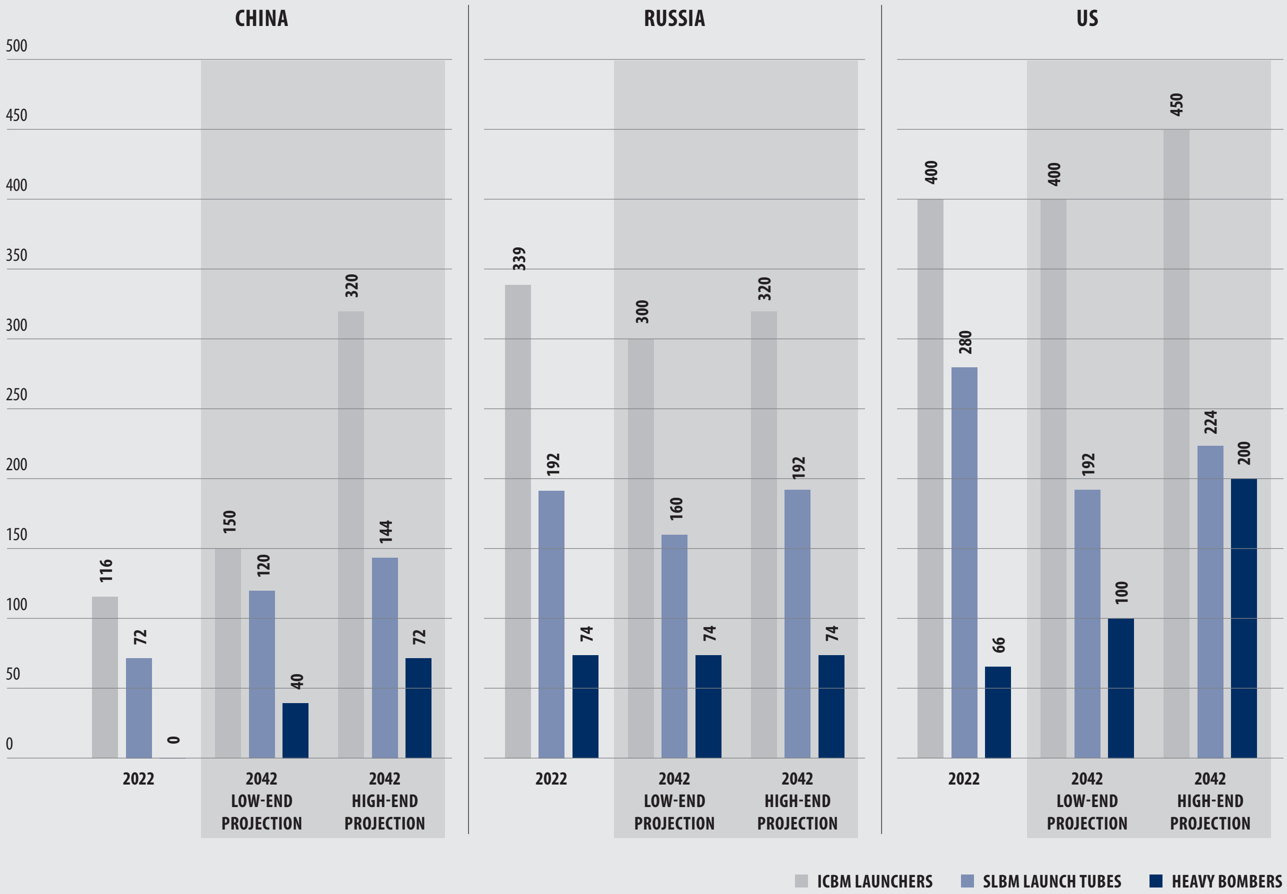
- The three parties could begin by exchanging data on their existing missile-defence efforts, including the numbers of deployed systems and performance of missile-defence interceptors and radars.
- They could then invite each other to verify the performance characteristics of interceptors through exhibition tests and potentially reciprocal visits to missile-defence facilities.
- The parties could then proceed to forswear capabilities that they have not yet deployed but that would likely play a major role in any 'thick' missile-defence system, such as space-based interceptors designed to neutralise attacking missiles in the mid-course phase of flight.
- Eventually they could move on to negotiate limits on missile-defence systems to ensure that no missile defence developed by any of the parties could be capable of neutralising a retaliatory intercontinental strike from the other parties.[37]

The final step would probably include a 'demarcation agreement' under which the sides would agree on the performance characteristics of strategic and non-strategic interceptors, as well as limitations on radar and interceptor performance, numbers and locations, as well as a probable ban on space-based missile-defence systems. The depth of the agreement would determine the level of verification required. Readily observable characteristics, such as the location and number of radars and interceptor launchers, including space-based systems, could probably be verified through unilateral intelligence collection – for example, from imagery and other satellites, commonly known as national-technical means (NTM). Others, such as the types of interceptors loaded into launchers, would require on-site inspections by officials from the relevant parties to the agreement. Movement towards a comprehensive missile-defence



BMD
Ballistic-missile defence could be incorporated into future arms-control agreements to ease anxieties. CREDIT: Greg Mathieson/Mai/Getty Images

Figure 2.1: **Chinese, Russian and US strategic nuclear forces: 2022 and 2042 projections**



Sources: IISS analysis; Military Balance+; *The Military Balance 2022*; National Air and Space Intelligence Center; US Department of Defense

treaty would be a long process with many complex technical hurdles, for example, the increasing basing of missile-defence interceptors on naval vessels that the parties are unlikely to open for intrusive on-site inspections. However, starting such a process with this distant objective in view would arguably build confidence, thereby producing momentum to reach this final goal.[38]

Limitations of Launcher Numbers

Some analysts have advocated a trilateral cap on China's, Russia's and the United States' strategic and theatre-range missile launchers across both conventional and nuclear systems, with a freedom to mix warheads to operator requirements.[39] Such an agreement would involve a single limit for a series of weapons, including ballistic- and cruise-missile launchers with a range of more than 475 kilometres, all SLBM launchers and all bombers with an unrefuelled range of more than 2,000 km. The agreement would not limit the warhead type of the associated missiles, but rather provide an overall cap that would limit the number of deployable nuclear or conventionally armed systems, and allow the freedom to mix between these different systems.[40] Under such an agreement, the US would include its *Aegis Ashore* sites located in Poland and Romania and, in return, submarine-launched cruise-missile launchers would be excluded from the agreement. By freezing missile launchers at approximately equal existing levels (approximately 1,000 units), such an agreement would significantly reduce arms-race pressures while allowing all parties significant latitude in designing a force posture optimal for its specific geographic and security requirements.[41]

Given China's resistance to transparency regarding its nuclear forces and states' general disposition to not compromise their security by revealing more information about their nuclear-force structure than necessary, the verification regime for such an agreement would have to be designed to minimise the level of intrusiveness. This would mean keeping visits by officials to other parties' facilities (on-site inspection) to a minimum.[42] Instead, data exchanges between the parties regarding numbers of launchers, their characteristics and location would be the fundamental basis for the verification regime. NTM would be the key for verifying compliance with regard to bombers, stationary offensive launchers (such as silo-based ICBMs) and SLBMs. Where this is not possible, for example, with mobile systems, then on-site inspection would be required. Such a division between the use of NTM and more intrusive measures follows the pattern of past arms-control agreements. SALT I and II focused primarily on systems such as ICBM and SLBM launchers, as well as bombers, which were verifiable by NTM. Mobile ICBM launchers were limited in SALT II but were verified with far greater confidence with on-site inspections under START I and New START. The primary challenges to this agreement, as proponents have pointed out, are not technical but political.[43]

The Political and Economic Roots of Arms Control

Given this mismatch between the widely understood notions of the military-technical sources of instability, arms-control proposals designed to deal with these instabilities and the erosion of established arms-control agreements, it is reasonable to ask whether arms control could be isolated from the broader deterioration of US relations with both Russia and China. The notion that arms limitation could and should be able to stand on its own and ideally should be isolated from politics has a long lineage. Since the nineteenth century, its advocates have argued that major powers should set aside their differences to pursue negotiated arms limitations in service of moral or humanitarian ideals and, in the nuclear age, simply survival.[44]

History shows, however, that arms control is deeply intertwined with politics and economics. Arguably, states' decisions to try seriously for arms-control agreements are influenced by domestic political and economic pressures. Just as arms racing is driven by political differences between states, so arms control only takes place when governments can come to some level of understanding regarding the fundamental framework of international order. When the combination of a supportive domestic environment and at least some shared interest in the current geopolitical status quo are present, then arms control is possible. When it is absent, it is not.

This section of the chapter will first address how domestic factors have impelled states to undertake serious arms-control negotiations. It will then outline the way in which relations between the major powers have shaped their decisions to enter into arms-control agreements. It will conclude by reflecting on the implications of this history for the current prospects for arms control between China, Russia and the US, arguing that both new bilateral (US–Russia, US–China) and trilateral (China–Russia–US) agreements are highly unlikely unless there are significant changes in domestic and international conditions.

Domestic Sources: US History

The US has been the outstanding pioneer of major-power arms control during the twentieth and early twenty-first centuries. It has also been the world's largest economy throughout this era, ultimately capable of besting any potential competitor in a long-term arms competition. This has meant that the domestic sources of the United States' arms-control policies have been based less on purely economic strains – though those were present – than on the decreased willingness of the US Congress to appropriate the funds to prosecute arms races with Washington's rivals.

At critical junctures, the US Congress has played a major role in limiting the ability of the US government to spend the amount of money necessary to compete with its nearest rivals. This was the case with the first significant post-First World War major-power arms-control agreement, the Washington Naval Treaty. Executive-branch plans to build the largest navy in the world encountered congressional opposition, stemming in part from the impulse to cut government spending to respond to the post-war deflationary crisis, but also from fears of provoking an arms race with the British and the desire to pare back executive prerogatives in foreign and defence policies that had grown during the First World War. A congressional assault on these spending plans, led by Republican senator William Borah, succeeded in securing an amendment to the naval appropriations bill that called for the new Republican president, Warren G. Harding, to convene a summit on naval-arms limitation, thus providing significant domestic political impetus for the administration's decision to convene a conference on this issue.[45]

During the late 1960s, largely because of the Vietnam War, congressional opinion again turned against executive military overstretch, this time regarding inflation-fuelling overspending on strategic nuclear and conventional arms. The Nixon administration's planned *Safeguard* ABM system passed the Senate by just one vote in August 1969, while other major programmes, such as MIRVs, also faced significant congressional opposition.[46] In 1971, the Democratic Senate majority leader Mike Mansfield pushed for a legislative amendment that would have cut US forces in Europe by half.[47] This domestic backlash against unrestrained strategic and conventional arms budgets played a significant role in incentivising the Nixon administration to conclude the SALT I agreements, including the ABM Treaty and the Interim Agreement on Strategic Offensive Forces, as well as the INCSEA agreement. It also drove the US to propose limits on conventional forces, including the Mutual Balanced Force Reduction negotiations. Once it had established its commitment to seeking arms-control agreements with the Soviet Union in the eyes of its congressional critics, the Nixon administration pressed forward with new systems, such as the UGM-96 *Trident* I SLBM and the B-1 *Lancer* bomber, that could otherwise have faced congressional opposition of an intensity approaching that to the administration's ABM programme.[48]

In the 1970s and 1980s, the US Congress often linked the modernisation of strategic arms with efforts by administrations to seek progress in strategic arms control.[49] In the early 1980s, the Reagan administration clashed with Congress over its arms-control strategy and plans to deploy the Missile Experimental (MX, subsequently named the LGM-118 *Peacekeeper*). Concerned with the administration's arms build-up and what they saw as an uncompromising negotiating stance that was impeding progress towards new agreements with the Soviet Union, critics in Congress negotiated changes to the US position at the START talks in exchange for congressional authorisation of a pared-down programme for the MX.[50] Thus, for the US, from the interwar period through to the end of the Cold War, congressional opposition to administration arms programmes that it has considered unnecessary, expensive and potentially dangerous has played a major role in impelling the executive branch towards arms-control negotiations and ultimately agreements.

For the United States' competitors, the financial strains of running an arms race with the world's largest economy have historically weighed most heavily in their decisions to seek arms limitation. Britain emerged from the First World War heavily indebted, reeling from deflation and requiring major cuts to defence spending to achieve its eventual aim of rejoining the Gold Standard.[51] Given these imperatives, it made sense to engage in arms-control talks with the US rather than undermine its economic recovery by engaging in a new naval race with Washington. Also suffering from the economic downturn in the aftermath of the First World War and with an economy at the most one-sixth the size of the United States', senior Japanese naval figures – most importantly navy vice minister and vice admiral Katō Tomosaburō – recognised that Japan could not afford to compete with Washington.[52] Under these conditions, agreed control with the world's largest economy seemed preferable to both London and Tokyo when compared to a potentially ruinous new arms rivalry.

GORBACHEV AND BUSH
Soviet president Mikhail Gorbachev and US president George H. W. Bush holding a joint press conference at the 17th G7 summit, July 1991. Russia's economic woes influence its decision to seek arms-control measures with the US. CREDIT: Dirck Halstead/Getty Images

Domestic Sources: Soviet/Russian History

For the Soviet Union, too, the opportunity to gain formal equality in strategic arms with an economy at least twice its size played a significant role in Moscow's decision to agree to strategic arms limitation. The USSR devoted enormous resources to its strategic nuclear-missile build-up in the 1960s, including up to 20% of its defence spending and the labour of over half a million people, as well as the prioritisation of high-tech components and expertise for its missile forces in an economy where these were in notoriously short supply.[53] For Soviet leader Leonid Brezhnev, SALT offered the opportunity to freeze this parity in launchers with the US, thereby solidifying this basic metric of parity with Washington at an affordable cost.[54]

Economic considerations were also important in Mikhail Gorbachev's decision to agree to a series of treaties that, while requiring major concessions from Moscow, would help to free up resources for his domestic reform programme. As the Soviet economy unravelled in the late 1980s and early 1990s, these included a treaty on intermediate-range missile forces without securing a strategic arms-reduction agreement or guarantees from the Reagan administration regarding its continued adherence to the ABM Treaty. The Soviet need for financial assistance from the US and other members of the G7 at their June 1991 London Summit was a key factor in Gorbachev's determination to override opposition from the Soviet General Staff and missile industry to outstanding points of contention on the START I treaty, which Gorbachev and US president George H.W. Bush signed that July.[55]

Since 1991, the Russian Federation has also had significant economic incentives to maintain bilateral strategic arms limitation with Washington, even when it has failed to achieve its other arms-control objectives. The Soviet collapse, the weakness of the economy and shrinking budgets left Moscow struggling to simply maintain the forces it had. Almost 25% of Soviet ICBM launchers and approximately half of its heavy-bomber force were suddenly in independent Belarus, Kazakhstan and Ukraine.[56] Though the Commonwealth of Independent States high command officially took charge of the ICBMs from December 1991, its real ability to control these forces, especially

TU-22M *BACKFIRE*
With the collapse of the Soviet Union, large portions of its nuclear arsenal are transferred and later dismantled among newly independent states. CREDIT: Sergei Supinsky/AFP/Getty Images

those in Ukraine, remained in doubt. Moscow also lost direct control over a significant proportion of the Soviet missile industry, with only one ICBM design bureau, the Moscow Institute of Thermal Technology, and one viable ICBM plant, in Votkinsk, remaining within the borders of the new Russian Federation. Production rates of new weapons systems declined, impairing the implementation of existing force-structure plans.[57]

In these circumstances, cuts to Russian strategic forces were almost unavoidable with or without arms-control agreements. Under significant financial constraints and encountering difficulties in maintaining force readiness, Russia implemented many of the reductions mandated by START I before the treaty formally entered into force in December 1994. Without viable production facilities for its existing ICBMs save for the single-warhead light RS-12 *Topol*, the Russian Ministry of Defence favoured ratification of START II, which required the elimination of MIRVed and heavy ICBMs.[58] In a 1998 interview, the then-commander of Russia's Strategic Rocket Forces, Vladimir Yakovlev, argued that ratification of START II was necessary on budgetary grounds.[59] Projections during the period suggested that, absent more financial support, Russian forces would naturally sink below START II levels even without a new agreement, necessitating further cuts to deployed warheads below the treaty's 3,000–3,500 limit if Moscow wished to maintain formal parity with Washington.[60] In March 1997, presidents Bill Clinton and Boris Yeltsin agreed that a future START III treaty would aim for an aggregate limit of 2,000–2,500 warheads. Yakovlev concurred with this warhead cap and stated that he might agree to one as low as 1,500, so as 'not to burden the national economy with crazy expenses, while at the same time maintaining the balance of power' with the US.[61] The US government appeared to share this assessment of the importance of Russia's financial difficulties in driving its arms-control strategy. Clinton told Yeltsin during a June 1997 meeting that further reductions through a START III agreement would be 'consistent with your economic needs and our security needs'.[62]

However, significant opposition from the nationalist and communist factions delayed ratification of START II, first in the Supreme Soviet of Russia and then in the new State Duma. Several attempts by the Yeltsin government to push the process forward stalled, in part due to domestic controversy over other issues between Russia and the West, such as

NATO expansion, the Anglo-American *Operation Desert Fox* against Iraq, NATO military intervention in Bosnia and Kosovo and US attempts to revise the ABM Treaty. START II was not ratified until 2000, and even then the Russian legislature added reservations regarding US ratification of a series of agreements designed to preserve the ABM Treaty. Russian President Vladimir Putin renounced START II on 14 June 2002, one day after the US withdrew from the ABM Treaty.[63]

Despite the ultimate demise of START II, Moscow continued to implement deep cuts in its strategic offensive arsenal along lines acceptable to the US, while failing to secure its objective of new bilateral limits on strategic defensive systems. It signed the Moscow Treaty (Strategic Offensive Reduction Treaty – SORT) in 2002 with its vague pledge to reduce strategic offensive warheads to between 2,200 and 1,700. Russia then signed the 2010 New START Treaty, pledging to further reduce warhead numbers to 1,550 and deployed ICBMs, SLBMs and heavy bombers to 700 units.[64]

US CONGRESS
Leaders of the US House and Senate Armed Services Committees, Representative Adam Smith from Washington State and Senator James Inhofe from Oklahoma, participating in a ceremonial gavel passing, November 2020. Significant bilateral support for future arms control appears highly unlikely.
CREDIT: Jim Lo Scalzo-Pool/Getty Images

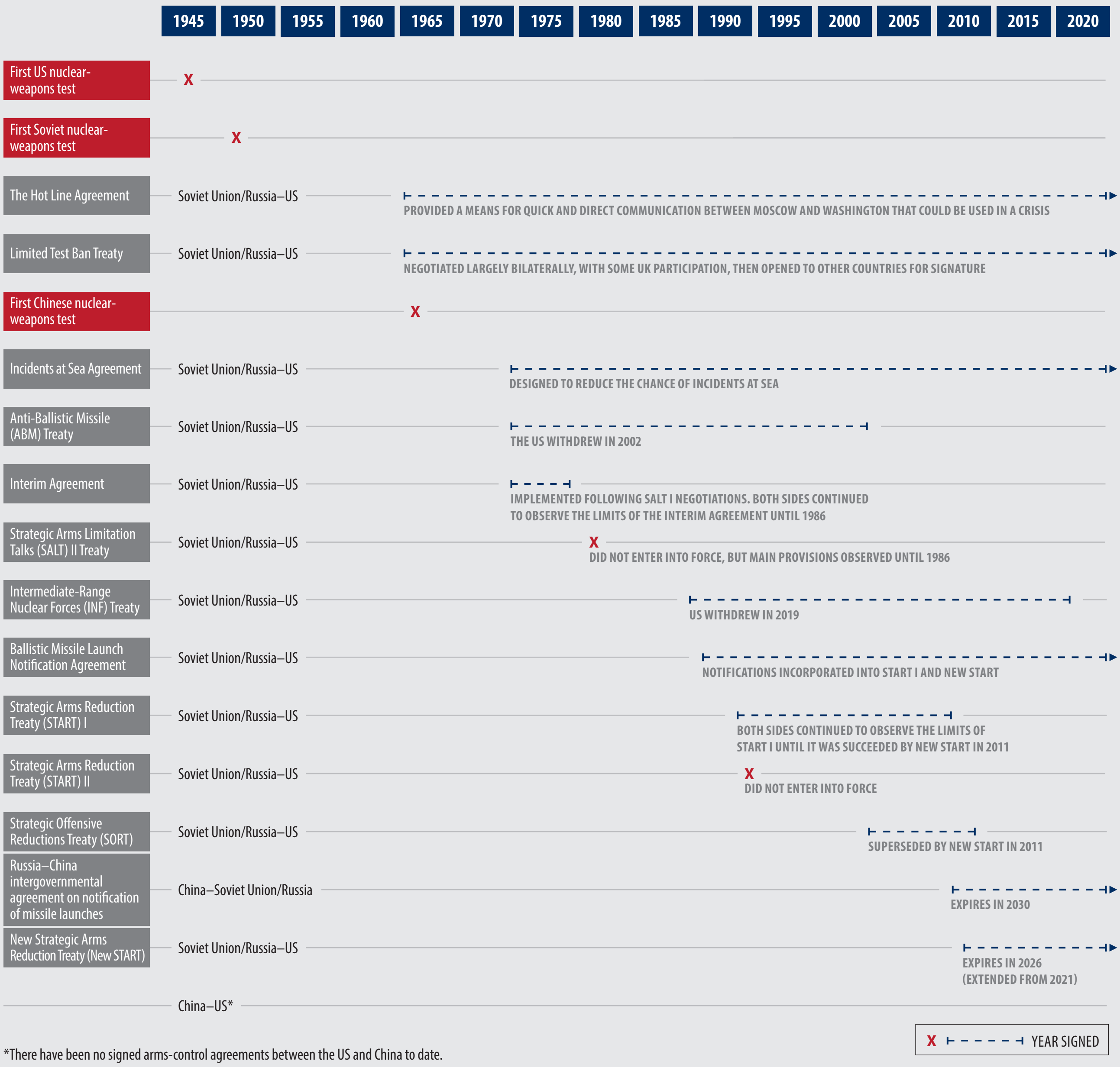
Current Domestic Conditions

Domestic politics and resource constraints have thus played a significant role in setting the stage for successful arms control by structuring the incentives of the major powers in a way that favours an agreement. Arguably the optimal domestic scenario for arms limitation is a US Congress willing to use its spending power to incentivise the presidential administration of the day to pursue new arms-control agreements, whilst at the same time the United States' competitors are under significant economic pressure to control their military spending.

Not many of these elements exist today. Despite high inflation in the US, voices calling for the reining in of defence spending through detente are rare.[65] It seems highly unlikely that the US Congress will revive its historical role of compelling the executive branch to take significant additional steps towards new arms-control agreements beyond urging efforts for a new arms-control agreement limiting NSNWs, a priority which is shared with the executive branch.[66] The congressional consensus appears to be that the Biden administration is making sufficient efforts to push arms control forward, and in the current climate of confrontation exacerbated by Russia's invasion of Ukraine and China's nuclear build-up, there is no question of holding any of the ongoing modernisation of US strategic forces hostage to significant changes in the administration's arms-control stance regarding Moscow or Beijing. Congress appears unwilling even to limit spending on programmes, such as the US homeland missile-defence system, that have consistently underperformed while absorbing significant amounts of federal dollars.[67] In the light of Russia's and China's revisionist behaviour combined with their nuclear-arms racing, it appears all but impossible to secure sufficient votes from Republicans and Democrats to achieve the two-thirds majority necessary for the advice and consent of the Senate to the ratification of any new arms-control treaty unless it imposed punishing limits on the other parties. Even the resumption of SSD with Moscow would likely encounter some opposition.

Though Russia is likely to suffer from increased resource constraints in the wake of its invasion of Ukraine, it is unclear whether these will be sufficient to compel it to negotiate any agreement that would be acceptable to the US Congress. The economic consequences of the war, including the contraction of the Russian economy, limited access to high-technology components and the likely eventual diminution of its oil and gas revenues, will mean that the Russian government may be increasingly poorly positioned to engage in an unlimited competition with the US, a state that already enjoys significant economic and technological advantages over Russia. Against this should be weighed the increased importance of nuclear weapons in Moscow's deterrence strategy during a period when its conventional forces both are depleted and have suffered a considerable blow to their prestige. While Russia will probably have reduced spending power and many

Figure 2.2: **Chinese, Soviet/Russian and US strategic arms-control agreements, 1945–2022**



*There have been no signed arms-control agreements between the US and China to date.
Sources: Arms Control Association, https://www.armscontrol.org/; US Department of State; Ministry of Defence of the Russian Federation, https://eng.mil.ru

pressing demands on resources, it could also prioritise its nuclear arsenal in this difficult economic environment, as it has throughout the 1990s and 2000s, making it less willing to deal on limiting its strategic and theatre-range nuclear forces.[68]

There seems to be little prospect that China will encounter any difficulties in meeting the demands of its military build-up, including that of its nuclear forces. Despite a relative economic slowdown in recent years, China's official defence budget will continue to grow at a significant rate – 7.1% in 2022 – with little sign that China's reduced growth will be reflected in more modest increases.[69] While it is highly likely that China's defence-budget figures do not fully capture the real defence burden, officially estimated at 1.3% of GDP, the US Department of Defense nevertheless assumes that the Chinese economy 'can support continued growth in defence spending for at least the next five to ten years'.[70] That could change if reductions in China's economic growth continue, but there is no sign yet of such a development. The recent appearance of approximately 300 new missile silos in northern China suggests that Beijing is willing to devote more resources to its strategic nuclear forces than it has done previously, constructing at a rate that rivals the Soviet Union during the height of its missile build-up against the US in the 1960s. China's emphasis on a civilian nuclear-fuel cycle, dependent on plutonium, also signals an ability to build up its nuclear arsenal with extreme rapidity.

Whether Beijing ultimately aspires to parity with the US and Russia in strategic nuclear forces is still unknown. For example, some analysts have suggested that China's new silo construction may be part of an elaborate 'shell game', in which Beijing would hide a smaller number of missiles in a larger number of silos in order to complicate a US counterforce strike.[71] However, it seems likely that economic constraints will not be a factor in preventing China from achieving nuclear parity with Washington and Moscow if Beijing decides to do so.

In sum, domestic factors do not seem to be running in arms control's favour at this time. There is no congressional pressure for the US to change its currently dormant arms-control positions, and while economic incentives to strike a new strategic arms agreement are theoretically present in Russia, they have yet to manifest themselves. By comparison, all such factors are non-existent in China. This correlation of factors is complicated by the fact that, for the first time since the interwar period, Washington is facing the prospect of a multipolar arms race. In the 1920s and into the 1930s, the US was able respond to congressional pressure to strike agreements with both Britain and Japan because both were labouring under significant economic constraints. A significant portion of the political elites in those countries recognised and were willing to engage in arms control as preferable to running an arms race with an economically superior power. At the time of writing, the chances of such permissive domestic circumstances materialising in both Moscow and Beijing simultaneously appear remote.

International Factors

Political differences between states lie at the heart of major-power competition and consequent arms-racing behaviour, so it is not surprising that arms control also requires a certain level of consensus between them in order to be successful. British attempts to engage Germany in talks on naval-arms limitation before the First World War were abortive, in large part because the two powers were divided on fundamental European security issues, notably Britain's *entente* with France and the question of its support for Paris in the case of a new Franco-German war. At the heart of Anglo-German rivalry also lay the issue of status. Berlin was simply not able to accept the relatively junior position that London had designated for it, while the British were unable to acquiesce to the growth of a new naval power that would be able to challenge the Royal Navy in the North Sea. This was reflected in disagreements over the ratio of capital ships that each side was willing to accept as part of any accord.[72] Effective management of these two interlinked issues of geopolitical disagreements and relative status has been necessary for enduring arms-control bargains.

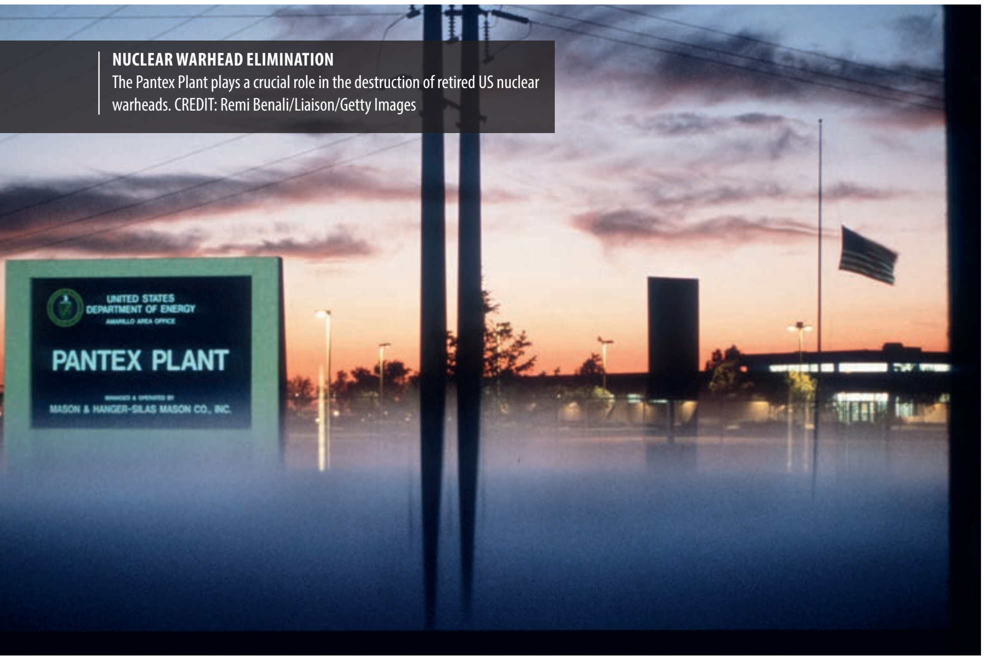
The Washington Naval Treaty, and associated agreements, showed that the management of key geopolitical differences and questions of relative status between major powers was possible given the right domestic incentives. The Four-Power Treaty between Britain, France, Japan and the US committed the contracting parties to respect the geopolitical status quo by 'respect[ing] their rights in relation to their insular possessions and insular dominions in the region of the Pacific Ocean'.[73] This rather lax agreement replaced the Anglo-Japanese alliance, marking the end of any threat of an Anglo-Japanese combination against the US. It also prevented Washington and London from jointly moving against Tokyo, thereby creating a diplomatic balance that complemented and reinforced the terms of the five-power Washington Naval Treaty on naval-arms limitation. This, combined with the Nine-Power Treaty governing future policy towards China, provided the geopolitical basis for the Washington Treaty system.[74]

The 5:5:3 ratio that governed capital-ship construction for the British Empire, the US and Japan was indicative of the relative status that each power was then willing to accept. After a century of naval dominance, Britain conceded that it would no longer be supreme, accepting that the US would share the claim to the world's largest navy – at least as symbolised by battleship tonnage. Washington agreed that its clear economic superiority would not be converted into the coin of major surface combatants for the time being. Japan, meanwhile, was willing to accept a position of global inferiority as compared to Britain and the US, but regional superiority versus both London and Washington and a position of relative seniority compared with the European navies, France and Italy, which were permitted a ratio of 1.75 each. Importantly, the question of geopolitical management and relative status were linked: as part of the agreement, the US and Britain agreed to limit the development of naval bases in the Western Pacific, thereby restraining their ability to enforce the terms of the Four-Power Treaty militarily and reinforcing Japan's regional superiority.[75]

SALT exhibited a similar joint understanding between the US and the Soviet Union regarding their relative status. The basic metric of the agreement was approximate nuclear parity between Washington and Moscow. The 1972 Interim Agreement on Offensive Forces froze the two superpowers at their existing force levels. While this did not equate to exact equality in all categories of systems, it arguably provided for rough parity between the two superpowers. The USSR placed a priority on reaching nuclear parity with the US throughout the 1960s, in large part to achieve political recognition from Washington as a peer. US acceptance of Soviet status as a peer superpower, for example through arms-control agreements, was a key objective of Moscow's detente strategy. For Washington, by contrast, recognition of Soviet strategic nuclear parity was a concession to the new reality rather than an achievement and drove efforts to maintain a technological edge in its nuclear forces, and to achieve conventional parity through arms control and theatre balance through a reliance on NSNWs. However, it was willing to agree to strategic nuclear parity to halt the ongoing Soviet build-up of long-range missile launchers that threatened to completely outstrip the US and undermine the US extended-deterrence guarantees in Europe and Asia. The watchword for SALT II of 1979 was 'equal aggregates'.[76] Under the complex terms of the agreement, both superpowers agreed to equal levels of strategic offensive arms, now expanded to include long-range bombers.[77] Thus, the SALT generation of strategic arms agreements was built on the mutual recognition of the US and the Soviet Union as peer superpowers.

The acceptance of the de facto division of Europe into US and Soviet spheres of influence was more implicit during the mid-Cold War arms negotiations than the division of the Asia-Pacific region during the interwar period. However, it was nevertheless an important component of the network of treaties that laid the foundation for SALT I and II, as well as a key element of the broader process of US–Soviet arms control and detente of which SALT was also a part. West German access to nuclear weapons – and, with them, Bonn's ability to revise the division of Germany through force – was a fundamental subtext of the 1963 Limited Test Ban Treaty and 1968 Non-Proliferation Treaty, which together effectively outlawed a German finger on the nuclear trigger. Further agreements regulating the division of Germany proceeded in parallel with SALT, notably the 1970 Treaty of Moscow wherein West Germany recognised Germany's post-war borders; the 1971 Four-Power Agreement on Berlin regulating a divided Berlin; and the 1972 Basic Treaty whereby West and East Germany recognised each other – while West Germany was forced to explicitly forgo any weapons-of-mass-destruction capabilities. These agreements recognised Soviet dominance of Eastern Europe de facto and renounced alteration of this situation by force but did not rule out – and arguably facilitated – peaceful change, a balance that the Helsinki Final Act of 1975 continued.[78]

The talks that led to the START I treaty began in the context of US–Soviet parity, but transformed into a means to manage Soviet decline and the consequences of its collapse (as would the Treaty on Conventional Armed Forces in Europe).[79] Washington succeeded in achieving arms-control goals – such as the complete elimination of all US and Soviet ground-based intermediate-range cruise missiles and IRBMs under the INF Treaty – that the Soviet Union had rejected five years previously. The signature of START I and II symbolised the Soviet Union's and the subsequent Russian Federation government's acceptance that, though it might be theoretically equal to the US in numbers of strategic weapons, it needed to concede significant advantages to Washington by agreeing to major cuts in prized weapons systems such as heavy ICBMs, de-MIRVing of all ICBMs (which was never implemented) and delinking talks on offensive and defensive forces. This retreat from previously impregnable negotiating positions was accompanied by significant domestic reform and Moscow's negotiated withdrawal from Eastern Europe and ultimately the former Soviet republics, as well as the rapid decline of its power relative to the US.[80]



NUCLEAR WARHEAD ELIMINATION
The Pantex Plant plays a crucial role in the destruction of retired US nuclear warheads. CREDIT: Remi Benali/Liaison/Getty Images

The transformed geopolitical conditions at the end of the Cold War meant that previously unacceptable arms-control measures became possible. During the late 1980s the US had rejected Soviet proposals for deep reductions in tactical nuclear weapons.[81] However, after the signature of the START I treaty, the George H.W. Bush administration decided to deepen nuclear cuts in view of the improved relationship with the Soviet Union, and at an accelerated pace given Gorbachev's increasingly tenuous hold on power and 'concern over the security of Soviet warheads'.[82] On 27 September 1991, hoping to stimulate reciprocal measures by Moscow, Bush announced that the US would unilaterally eliminate all ground-launched, short-range nuclear weapons and withdraw tactical nuclear weapons from its ships, attack submarines and naval aviation. 'Many' of the naval weapons would also be eliminated.[83] In response, Gorbachev pledged to destroy all Soviet nuclear artillery shells, tactical missile warheads and nuclear mines, as well as to withdraw tactical nuclear weapons from ships and submarines. 'A portion' of these, as well

RUSSIA–UKRAINE WAR
Russia's 2022 invasion of Ukraine has frozen progress on arms control between Moscow and Washington. CREDIT: Chris McGrath/Getty Images

as those for Soviet naval aviation and ground-launched surface-to-air missiles, would be destroyed and the rest kept in central storage.[84] While implementation of these unilateral initiatives has been dogged by transparency problems, particularly on the Russian side, it is nevertheless true that the dramatic international political developments of the late 1980s and early 1990s opened the way for enormous cuts in Washington's and Moscow's non-strategic nuclear arsenals.[85]

Current International Conditions

Just as the domestic political foundations for new arms-control agreements are currently lacking, so none of the international factors that have formed the basis of new arms-control treaties appear to be present today. Profound disagreements regarding their relative status and related geopolitical tensions lie at the root of the United States' relations with both Russia and China, meaning that – barring the emergence of a new Gorbachev-like figure in either Moscow or Beijing – the diplomatic foundations for successful arms-control agreements are unlikely to be present in the near future.

Prospects for Russia–US Arms Control

Russia has been dissatisfied with its status for 30 years. Arguably the pattern of US–Russia relations since the end of the Cold War has been characterised by a series of attempts to 'reset' the relationship, which have raised Russian hopes that Washington will recognise the Kremlin's vision of its rightful place in the international order, only for the reality to fall short of its aspirations. In Moscow's eyes, US offers of partnership have unravelled in this way at least three times: under the presidencies of Clinton, George W. Bush and Barack Obama. The US and its allies' interventions in Bosnia, Kosovo, Iraq and Libya have been key symbols, in the Kremlin's view, of the United States' unwillingness to take Russian interests into account.[86]

Such concerns with status also are also linked inextricably with a growing dissatisfaction with the European security order, meaning the network of institutions and agreements regulating security issues on the continent. The ongoing patterns of NATO and EU expansion have underlined the extent to which Russia now sits on the margins of that order – an order in which, at least in Moscow's view, it should play a central role. Putin has consistently expressed such sentiments in his public statements and these concerns are also present in Russia's official Military Doctrine.[87] For its part, through its invasion of Ukraine and other actions Russia has sought to undermine key elements of the European order that the US, its allies and non-NATO European states value, including the INF Treaty, the Vienna Document, the Chemical Weapons Convention, the Treaty on Open Skies and the Helsinki Final Act. For the US, Russia is a revisionist power that has rejected attempts to engage it as a constructive partner; for Russia, the US definition of partnership equates in fact to subordination.

Russia's war in Ukraine lies at the centre of the current crisis in European security, and Moscow's diplomacy leading up to its 2022 invasion is indicative of the fundamental disagreements existing between the parties and how they affect arms control. In December 2021, Moscow issued two documents: one, a treaty for signature with the US; and the other, an agreement with NATO. The documents outlined a number of terms that were completely unacceptable to the US and its allies, but nevertheless fit with the broad pattern of grievances that Moscow has expressed since the 1990s: a legally binding halt to NATO enlargement, the withdrawal of NATO forces from the territory of its Eastern European members, no further military cooperation with non-NATO former Soviet states, no more NATO partnerships and the removal of US nuclear weapons from Europe.[88] The US responded to Russia's initiative with a counterproposal, designed to develop areas of potential common ground on confidence-building measures, while rejecting limits on NATO expansion and withdrawal of forces.[89] Russia, however, remained committed to legally binding and explicit limits on the United States' and NATO's military forces and future growth, reinforcing suspicions in the West

BIDEN AND XI
While arms control with China is desirable from Washington's perspective, Beijing shows little interest in engaging with the issue.
CREDIT: Mandel Ngan/AFP/Getty Images

that Moscow's proposals were 'designed to fail' and provide a diplomatic pretext for Russian military action.[90] Russia's subsequent attack strongly indicates that it judges any near-term progress on arms control as less important than achieving its objectives in Ukraine by force, and both sides have ruled out reconvening the SSD in the current circumstances.[91] There is almost no likelihood of any re-engagement on arms control with Russia until at least a ceasefire is achieved in Ukraine, if not a final settlement of the conflict. Even then, the blow to Russian credibility resulting from its actions will probably raise the verification requirements for new arms-control agreements, further complicating any negotiation.

Prospects for Chinese–US Arms Control

The current state of US relations with China is marginally less confrontational but they exhibit the same fundamental disagreements over relative status and geopolitical questions that will impede any significant progress on arms control. Chinese diplomatic rhetoric is replete with complaints regarding the United States' hegemonic aspirations and disregard of China's interests, while Beijing refuses to be drawn into substantive arms-control discussions with the US (see below).[92] Moreover, Beijing's stated ambition to deploy a 'world-class military' or 'worldwide first-class military' by 2035 in its 2019 defence White Paper 'China's National Defense in the New Era' also points to the growing importance of its military power as a metric of China's status and the implicit recognition that it still lags significantly behind its potential rivals in achieving a military consonant with its understanding of its global role.[93]

There seems to be little prospect that US–China disagreements over key issues, such as the long-term future of Taiwan, China's maritime claims and Beijing's expansion of its overseas-basing network, will be resolved soon. China continues to develop its capabilities to take Taiwan by force, with the commander of US Strategic Command (STRATCOM) estimating that it could have the capacity to do so by 2027 'if not sooner'.[94] While the US officially maintains its policy of 'strategic ambiguity' over the extent to which it would intervene to assist Taiwan in the event of a Chinese invasion, a series of recent statements by President Joe Biden making a greater commitment to defend the island in the event of Chinese action suggest that at least some within the current administration, including the president himself, believe that greater clarity is required to deter Beijing.[95] Brunei, Indonesia, Malaysia, the Philippines, Taiwan, the US, Vietnam and China remain at loggerheads over Beijing's maritime claims in the South China Sea.[96] Rather than showing any willingness to discuss its future basing plans with Washington, Beijing's recent security pact with the Solomon Islands and efforts to draw other Pacific Island nations into a broader security agreement indicate that it is ready to intensify its efforts to secure a network of bases within striking distance of US allies. At this moment, it appears more likely that US and Chinese competition on overseas basing will intensify rather than diminish.[97]

In sum, it seems highly unlikely that the US will be able to reach the kind of framework for managing key areas of dispute with its nuclear rivals or come to an understanding regarding their relative status in a way that has historically supported the successful conclusion of arms-control agreements.

Geopolitical Competition Drives Arms Racing and Competitive Arms Control

With no domestic political or economic constraints on the means of any side to compete, current divergences between China, Russia and the US over their respective status and related geopolitical questions will continue to drive arms racing and ensure that any arms-control negotiations remain highly competitive in nature. The basic political and economic conditions outlined above incentivise arms-racing behaviour, with states opting for destabilising nuclear and conventional postures employing new technologies in order to further their broader strategic aims.[98] Therefore, while there are many potential initiatives to limit missile systems that are theoretically plausible and would increase stability, states are unlikely to take them up without clear avenues to managing the deeper political and economic roots of competition.

If there are substantive diplomatic exchanges between the parties on these issues – something that, given the suspension of the SSD in the wake of Russia's invasion of Ukraine and China's continued refusal to engage in any meaningful arms talks, cannot be assumed – then we are likely to see the parties promulgate highly competitive negotiating positions that will seek to constrain areas where opposing parties hold the advantage, while limiting restraints in fields where they enjoy a lead.[99]

Even before the suspension of the US–Russia SSD in February 2022, this tendency was apparent. The turn to a more competitive arms-control stance is clear in the evolution of Moscow's negotiating position over the past decade. During negotiations on New START Russia initially insisted on limits on missile-defence systems as a precondition for any agreement, but eventually – and with the intervention of then-president Dmitry Medvedev – conceded that the treaty would cover strategic offensive forces only and confined its misgivings regarding missile defence to a unilateral statement.[100] After the conclusion of New START, Russia began arguing for an 'integrated approach' to a new arms-control agreement, including missile defences, but also long-range conventional missiles of the type that have the potential for counterforce operations.[101] Since 2020, it has rebranded these concerns as the 'new security/strategic equation', arguing that future arms-control agreements would have to address, in the words of Deputy Foreign Minister Sergei Ryabkov, 'all nuclear and non-nuclear weapons that are capable of accomplishing strategic tasks, with particular attention to means usable for launching a first strike to neutralise or weaken the deterrent potential of the other side', as well as missile defences.[102] Such limits would have the effect of reducing the conventional-strike threat to Russia significantly, particularly in a broad interpretation that would limit the build-up of US shorter-range systems capable of striking Russia near its borders. Moscow's formulation, restricting limitations to weapons able to accomplish 'strategic tasks' and attack the nuclear-deterrent forces of the other side, could arguably leave much of its own theatre-range arsenal – unable to attack the US homeland and strategic forces, but able to strike European NATO allies – free from constraints.[103]

The US, by contrast, has focused on further cuts in strategic nuclear offensive forces, and on the expansion of talks to include new exotic strategic offensive weapons and Russia's large stockpile of NSNWs. Russia is likely to see the US position as equally competitive, suspecting that Washington is seeking to restrain Moscow in the areas where it holds a clear advantage while refusing to broaden the talks to cover areas such as high-precision counterforce weapons where the US continues to hold a lead – now more than ever after the poor performance of such Russian systems in Ukraine and the running down of its stocks during the war there. The debate among civilian analysts over potential US and NATO responses to Moscow's possible use of nuclear weapons during the Russia–Ukraine war demonstrates the value of conventional counterforce systems to the Alliance: they provide a credible non-nuclear military response to limited Russian nuclear use.[104] Washington and its allies are likely to judge that such advanced conventional weapons have significant deterrent potential in future scenarios in which Moscow may threaten to employ a small number of nuclear weapons for battlefield or political advantage. Thus, the chances of the US putting such capabilities on the table as part of any new arms-control agreement are very remote. Meanwhile, Moscow is likely to rely more on its NSNWs when faced with the combination of depleted conventional capabilities due to the war in Ukraine and the need to offset NATO's advanced conventional systems, making it even more resistant to controls on NSNWs than it has previously been.

China's position on arms control has been even more competitive, refusing to engage in substantive talks on its build-up while it continues to develop a force that can help its broader geopolitical goals.[105] In doing so, China is arguably pursuing a similar strategy to previous rising powers, refusing any arms-control restraints on its strategic and theatre forces while it still enjoys the economic potential for further growth. This is roughly the same strategy pursued by Germany against Britain before the First World War, by the US against Britain before the Washington Naval Treaty and by the Soviet Union against the US before the Interim Agreement on Offensive Forces. Beijing will likely maintain its position of ruling out substantive arms-control talks in either a bilateral or trilateral format until it has achieved a force that it judges necessary to realise its ambition to become an equal peer with the US and likely achieve a force capable of accomplishing an invasion of Taiwan while either dissuading the US from intervening entirely or defeating the US conventionally while deterring US nuclear first use.

Conclusion

This chapter has sought to argue that a shared military-technical understanding of stability is necessary but not sufficient to achieve effective arms control between major powers. In addition to a shared conception of strategic stability, the right contextual factors also must be in place: principally domestic political or economic limitations that prevent the sides' respective militaries from engaging in an unrestrained competition, a basic consensus between the parties regarding their relative international status, as well as effective management – if not resolution – of key geopolitical disputes between them.

This chapter has argued that China, Russia and the US have a broad common understanding regarding the military-technical requirements for strategic stability, opening the way to a variety of theoretically viable arms-control agreements. However, hardly any of the other preconditions that have incentivised arms-control accords in the past appear to be present and, given the significant countervailing forces, those that are may not be sufficient to bring the three major powers together to work out new agreements. There is unlikely to be significant progress on arms control until the following happen:

- One or more of the parties encounters domestic political or economic constraints on their ability to prosecute an arms competition with the others.
- There is significant progress in the diplomatic management of the geopolitical disputes and related disagreements over relative international status that drive arms racing between China, Russia and the US.

Until these two things happen, theoretically stabilising arms-control agreements will remain just that: theoretical.

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CHAPTER THREE

China

China has expanded its missile capabilities over recent decades to support a range of critical national-defence priorities. Today, China possesses a considerable arsenal of ballistic and non-ballistic missiles, including cruise missiles and hypersonic boost-glide systems. Its ballistic- and cruise-missile development programmes have been described by parts of the US intelligence community as 'the most active and diverse … in the world'.[1] While China's missile capabilities have long supported its strategic nuclear-deterrence objectives, in recent decades Beijing has substantially expanded its inventory of conventional and dual-capable missiles. This inventory has been expanded without any formal arms-control constraints. Notably, as a non-party to the 1987 Intermediate-Range Nuclear Forces (INF) Treaty that bound the United States and Russia, Beijing built out a particularly large inventory of ground-launched short-, medium- and intermediate-range ballistic and cruise missiles (respectively SRBMs, MRBMs, IRBMs and GLCMs).[2] Many of these missiles are thought to offer a considerable degree of precision against fixed and, for a smaller number, possibly mobile targets. China has also sought to better integrate advanced sensors and other enabling technologies to pursue anti-ship ballistic missiles (ASBMs), amongst other capabilities.

While China's development of a diverse array of conventional and dual-capable missiles has been widely acknowledged by Western and regional experts for years, new developments roughly beginning in 2020 point to significant shifts in the role of missiles in China's pursuit of strategic nuclear deterrence. In short, China is pursuing what is by all accounts the most substantial shift in its nuclear posture in decades. In 2021, the US intelligence community's Annual Threat Assessment bluntly stated that China 'will continue the most rapid expansion and platform diversification of its nuclear arsenal in its history' – an assessment later corroborated by the discovery of three new large silo fields for intercontinental ballistic missiles (ICBMs).[3] It added that this diversification included the pursuit of 'a larger and increasingly capable nuclear missile force that is more survivable, more diverse, and on higher alert than in the past, including nuclear missile systems designed to manage regional escalation and ensure an intercontinental second-strike capability'.[4] The drivers behind China's ongoing quantitative

Key takeaways

EVOLVING NUCLEAR POSTURE
In the Xi Jinping era, China's nuclear forces have received particular attention amid broader military modernisation efforts across the People's Liberation Army.

A LARGER LAND-BASED FORCE
Three large, recently discovered silo fields, as well as the modernisation of China's mobile intercontinental-ballistic-missiles forces, suggests that China's strategic nuclear forces will continue to improve qualitatively and quantitatively.

DEVELOPMENTS AT SEA
Development and deployment of a new nuclear-powered ballistic-missile submarine and associated submarine-launched ballistic missile will allow China to hold at risk additional targets in the United States.

DRIVERS FOR CHINA'S BUILD-UP
Chinese leaders may perceive a heightened probability of general conflict with the US and may thus calculate a more robust nuclear deterrent to be necessary to induce caution in the US.

PROSPECTS FOR DIALOGUE
Despite US attempts to engage with China on strategic stability, there are slim prospects for substantive dialogue in the near term.

and qualitative nuclear modernisation remain contested amid few authoritative explanations from senior Chinese leaders, extending to Chinese President Xi Jinping, who has spoken largely in general terms about '[accelerating] the construction of advanced strategic deterrent' capabilities.[5] An anonymous Chinese official source, described as 'close to the leadership' of China in a newspaper report, said that 'China's inferior nuclear capability could only lead to growing US pressure on China', suggesting that the build-up is due to general concerns about coercion and potentially crisis bargaining.[6] But, in general terms, there is no unified, authoritative explanation for the ongoing nuclear-force expansion and debates as to the cause or causes of this remain unresolved.

In light of these ongoing shifts and longer-running trends, this chapter surveys China's contemporary missile-force structure, its relationship with its changing nuclear-force posture and the implications of these developments for strategic stability vis-à-vis the US.

China's Nuclear Posture and Modernisation

China's strategic nuclear forces comprise largely land- and sea-based ballistic missiles operated by the People's Liberation Army Rocket Force (PLARF) and PLA Navy (PLAN). The land-based component of China's nuclear forces comprises numerous *Dong Feng* (DF)-series ballistic missiles and is operated by the PLARF. Beijing employs multiple basing modes for its strategic missiles, including road-mobile integrated transporter erector launchers (TELs) and mobile erector launchers and missile silos. A limited number of older liquid-fuelled ICBMs may still employ a roll-out-to-launch basing mode.[7]

The PLARF was formally established in 2016 pursuant to military reforms announced by the Chinese leadership in 2015.[8] It formally replaced the People's Liberation Army (PLA) 2nd Artillery Corps, which had been created in 1966. As an organisation, the PLARF is a full-fledged branch of the PLA and reports directly to the Communist Party of China's (CPC) Central Military Commission (CMC). Xi, in his capacity as chairman of the CMC and commander-in-chief of the CMC Joint Operations Center, exercises ultimate authority over the PLARF (along with other branches of the PLA).[9] Command authority for the PLARF's nuclear forces and dual-capable units is thought to be dynamic between peacetime and wartime, with the latter resulting in nuclear units coming under the direct control of the CMC.[10] Operational control of exclusively conventional missile units is more complex, with the PLA's theatre commands playing a role in the oversight of these units. The PLARF is headquartered in Beijing and is supported by a Staff Department, Political Work Department, Equipment Department and Logistics Department. Outside of Beijing, the PLARF's main subdivision is known as a 'Base' (an organisational term and not a specific, geographically distinct facility). There are nine known Bases, numbered 61 through 69. Bases 61–66 are operational missile units while the remainder play various roles related to logistics, support, training, missile testing and nuclear-stockpile management.[11] The types of missiles under command vary from operational base to operational base, with some, such as Base 61, comprising primarily short- and medium-range missiles to hold Taiwan-based targets at risk, and others, such as Base 66, nearly exclusively comprising ICBMs.[12] Each PLARF Base is further subdivided into missile brigades, which vary in number across bases, and a range of support, communications, training and maintenance regiments. There are at least 39 known PLARF missile brigades. As of January 2022, the PLARF is commanded by General Li Yuchao, who is also an alternate member of the 19th Central Committee of the CPC.[13]

In the Xi era, missile forces have received particular attention amid broader military-modernisation efforts. In December 2012, shortly after becoming general secretary of the CPC, Xi visited the then-2nd Artillery Corps (later renamed the PLARF), reconfirming long-standing

THE PLARF
China's current defence minister, General Wei Fenghe, formerly commanded the then-2nd Artillery Corps (later renamed the PLARF) at a moment of growing prominence for the organisation in the PLA. CREDIT: Chip Somodevilla/Getty Images

Chinese nuclear policy on the occasion. General Wei Fenghe, who had taken command of the 2nd Artillery Corps shortly before Xi's elevation to general secretary, would go on to become China's minister of national defence and a state councillor in 2018; Wei had been elevated to the CMC, the apex military decision-making body of the CPC, a year prior. Wei's perceived proximity to Xi and his seeming importance in implementing Xi's 2015 structural reforms of the PLA suggested growing prominence for the PLARF. It remains unclear whether the apparent change in the trajectory of China's missile-force modernisation – particularly with regard to its nuclear forces – was a product of greater input or advice from military leadership, who have traditionally been less involved in this area. Planned changes to China's force posture could also be a result of Xi taking a view of nuclear weapons and deterrence that diverges from that of his predecessors. Amid greater expectations of possible conflict with the US, Xi could see a more robust nuclear deterrent as necessary to deprive the US of incentives to resort to nuclear use or coercive nuclear threats to offset current and future conventional disadvantages in the Indo-Pacific theatre. This theory for the case for a nuclear build-up could also be bolstered if Xi perceives Russia's substantial nuclear-weapons arsenal as having imbued the Western response to Moscow's invasion of Ukraine with a high degree of caution.

Map 3.1: **Ranges of China's nuclear-armed, land-based ballistic missiles**

Sources: *Asia-Pacific Regional Security Assessment 2022*; IISS; US Department of Defense

NOTE: Ranges are approximate, and shown for illustrative purposes only.

China's Evolving Intercontinental Missile Forces

China currently deploys two types of large, liquid-propellant ICBMs, the DF-4 (CH-SS-3) and DF-5 (CH-SS-4). The latter of these, which is the largest deployed ballistic missile in China and is based exclusively in silos, exists in at least two variants, the DF-5A (CH-SS-4 Mod 2) and the DF-5B (CH-SS-4 Mod 3). The latter of these is modified to accommodate multiple independently targetable re-entry vehicles (MIRVs). A third variant, the DF-5C, has been referenced in certain official US documents describing China's nuclear forces, but few details are available about the nature of this system.[14] Though modernised, the DF-4 and DF-5 family of missiles are considerably older than the rest of China's nuclear forces, with initial limited deployments for each beginning in the late 1970s (DF-4) and early 1980s (DF-5). The DF-4 may be on the verge of being fully phased out. Beginning in 2006, China deployed its first road-mobile solid-propellant-based ICBMs with the DF-31 (CH-SS-10 Mod 1) and a slightly longer-range variant, the DF-31A (CH-SS-10 Mod 2). In 2017, at a parade commemorating the 90th anniversary of the PLA's founding, China revealed an improved launcher for this system, designated the DF-31AG.[15] The DF-31AG features an integrated TEL instead of a towed mobile erector, which could enhance the durability, mobility and resilience of the launcher. It is unknown if the DF-31AG introduces any changes to the missile itself, but at least one authoritative US intelligence-community publication has suggested the possibility of a payload-section difference – perhaps for multiple warheads.[16] Uncertain US estimates, citing 'Chinese media reports', have also indicated that a DF-31B variant may exist.[17] The last component of China's

DF-31AG
A Chinese DF-31AG ICBM is shown in a military parade in Beijing to mark the 70th anniversary of the founding of the People's Republic of China, 1 October 2019. CREDIT: Greg Baker/AFP/Getty Images

land-based intercontinental missile force is the DF-41 (CH-SS-20), a solid-propellant-based missile deployed on an integrated TEL featuring MIRVs. The DF-41 has been fielded, according to US intelligence assessments.[18] The DF-41 will also be deployed in silos and possibly in a rail-mobile configuration as well. With the exception of the DF-5B and the DF-41, all of China's ICBMs feature a single warhead. The DF-5A is thought to feature a single five-megaton warhead, which is likely the largest-yield nuclear-warhead type currently deployed in the arsenal of any nuclear power. Across this set of fielded capabilities, including road-mobile and fixed systems, China operates more than 100 total intercontinental missile launchers.

While China's intercontinental missile forces saw only iterative changes over decades, Beijing appears to be in the process of implementing the most significant overhaul in the size of this force in its history. In 2021, commercial imagery analysis by non-governmental analysts in the US revealed construction activities at three new and previously unknown sites that each appeared to contain scores of missile silos.[19] Admiral Charles A. Richard, the commander of US Strategic Command, has testified that the US believes each of these three silo fields to contain approximately 120 silos.[20] Richard has also expressed the view that China's expanding land-based missile force points to a 'strategic breakout', which could result in an 'emboldened PRC that possesses the capability to employ any coercive nuclear strategy today'.[21] The US appears to assess that these new silos will be equipped with DF-31A ICBMs, supplementing existing silo-based DF-5A and DF-5B ICBMs; other ICBMs, such as the DF-41, may go on to arm these silos.[22] The new silo fields are located at sites near Yumen (Guazhou), Hanggin Banner (Ordos) and Hami – all in north-western China. Each of these sites remains incomplete as of August 2022 and satellite imagery shows excavation activities, the erection of temporary dome shelters and other related construction activities at all three sites. The silos remain unacknowledged by official Chinese sources; Chinese state media have repudiated reports of the new silo fields as analytically flawed and some commentators have insisted that the silos are foundations for wind turbines.[23] The addition of new silos represents a significant shift in the broader trajectory of Chinese nuclear modernisation, which had seen a growing emphasis on road-mobile launchers. To potentially arm missiles in these silos, Beijing is expected to expand its production of weapons-useable fissile material.[24] The US has assessed that China may have 'up to 700 deliverable nuclear warheads by 2027' and that the country's leadership 'likely intends' to seek 'at least 1,000 warheads by 2030'.[25] Each of these assessments represents a significant uptick from earlier projections that China would look to double its stockpile of warheads, which, as of 2020, were estimated to be in the 'low-200s'.[26]

Beyond the quantitative expansion of its land-based intercontinental missile force, China is pursuing qualitative improvements as well. Notably, Beijing is in the process of flight-testing intercontinental hypersonic boost-glide vehicles. In 2020, General Terrence J. O'Shaughnessy, the former commander of US Northern Command and the North American Aerospace Defense Command, said that China had started testing 'an intercontinental range hypersonic glide vehicle – similar to the Russian *Avangard*, which is deployed on a ground-launched ICBM booster – which is designed to fly at high speeds and low altitudes, complicating [the United States'] ability to provide precise warning'.[27] In July 2021, China tested a long-range glider at intercontinental ranges after first inserting it into orbit.[28] The tested system was launched from within China and covered 40,000 kilometres – roughly the circumference of the Earth – before making impact on Chinese soil. The glider flew for more than 100 minutes, which is the longest recorded flight time for 'any land attack weapon system of any nation to date', according to US Strategic Command.[29] As of mid-2022, there is no evidence or known published intelligence assessment suggesting that China intends to field such a weapon as a strategic delivery system. The test may have been a product of necessity: an intercontinental hypersonic glider cannot be tested on a lofted trajectory like a ballistic missile, so to ensure impact on a target in China at sufficiently long ranges, initial orbital insertion may be advantageous. In general terms, however, China can be expected to move towards the deployment of a long-range hypersonic glider on a ballistic-missile booster in the future. The primary attraction of a long-range glider would be its ability to evade US mid-course exo-atmospheric missile-defence systems, which Beijing fears could be used to negate a significant portion of its residual second-strike capability if used after a conventional or nuclear attack on its own nuclear forces.

China's Sea-Based Strategic Missile Force

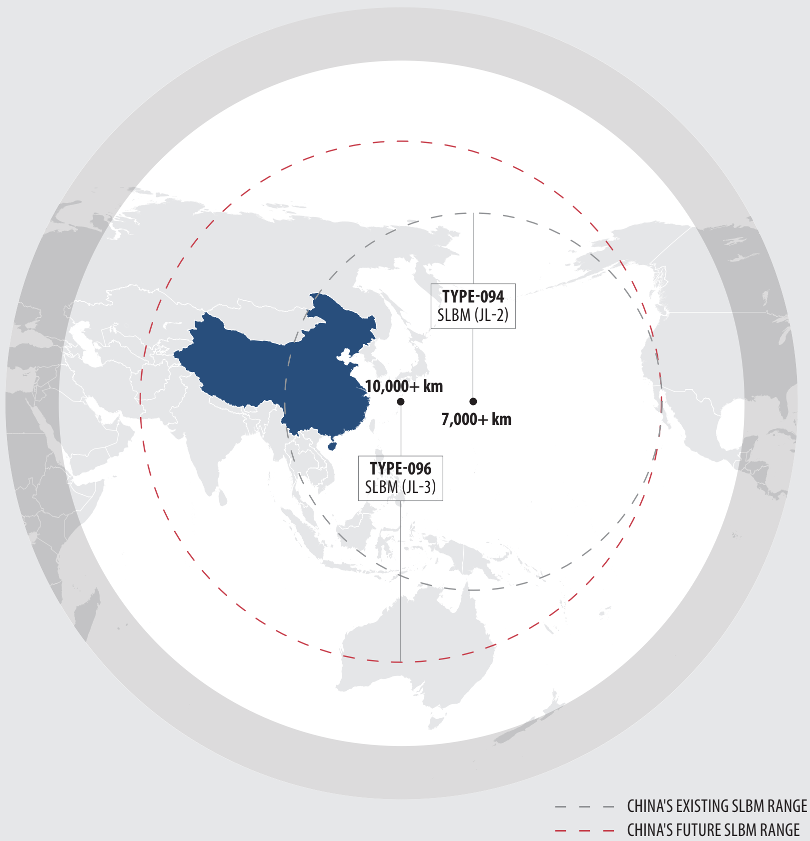
The PLAN currently operates six Type-094 (*Jin*) nuclear-propulsion ballistic-missile submarines (SSBNs), each capable of carrying up to 12 JL-2 (CH-SS-N-14) submarine-launched ballistic missiles (SLBMs) for a total sea-based strategic retaliatory capacity of 72 single-warhead missiles. The PLAN is currently in the process of developing a successor SSBN – the Type-096 – which will be armed with a new SLBM, the JL-3. Both JL-series SLBMs are solid-fuel systems capable of reaching intercontinental distances. The JL-2, however, is thought to have a range capability of some 7,000 km, which would require the SSBNs carrying these missiles to seek safe egress from their berths in the South China Sea and enter the Western Pacific to hold at risk targets in the US homeland. The PLAN is not known to carry out a continuous at-sea deterrence mission, opting instead to base its SSBNs within the South China Sea at the Longposan base on Hainan Island.[30] The next-generation JL-3 missile may be a larger missile with greater range, which would either reduce or obviate entirely the need for Chinese SSBNs to leave the South China Sea in a conflict. The JL-3 may also offer a MIRV capability, but this is not known with any

Figure 3.1: PLARF nuclear-missile inventory

<table>
<tr><th>NAME</th><th>RANGE (KM)</th><th>WARHEAD TYPE AND NUMBER</th><th>BASING OPTION</th><th>NUMBER OF STAGES</th><th>NUMBER OF LAUNCHERS (ESTIMATED)</th><th>INITIAL OPERATIONAL CAPABILITY</th></tr>
<tr><td>DF-4 (CH-SS-3)
Type – ICBM
Fuel type – Liquid</td><td>5,500+</td><td>NUCLEAR X 1</td><td>ROLL-OUT-TO-LAUNCH</td><td>2</td><td>10</td><td>1980</td></tr>
<tr><td>DF-5A (CH-SS-4 Mod 2)
Type – ICBM
Fuel type – Liquid</td><td>12,000+</td><td>NUCLEAR X 1</td><td>SILO</td><td>2</td><td rowspan="2">20</td><td>1980s</td></tr>
<tr><td>DF-5B (CH-SS-4 Mod 3)
Type – ICBM
Fuel type – Liquid</td><td>12,000+</td><td>NUCLEAR X MULTIPLE</td><td>SILO</td><td>2 + PBV</td><td>2015</td></tr>
<tr><td>DF-21A (CH-SS-5 Mod 2)
Type – MRBM
Fuel type – Solid</td><td>1,750+</td><td>NUCLEAR X 1</td><td>ROAD-MOBILE TEL</td><td>2</td><td rowspan="2">80</td><td>1996</td></tr>
<tr><td>DF-21E (CH-SS-5 Mod 6)
Type – MRBM
Fuel type – Solid</td><td>1,750+</td><td>NUCLEAR X 1</td><td>ROAD-MOBILE TEL</td><td>2</td><td>2016</td></tr>
<tr><td>DF-26 (CH-SS-18)
Type – IRBM
Fuel type – Solid</td><td>3,000+</td><td>DUAL-CAPABLE (NUCLEAR X 1)</td><td>ROAD-MOBILE TEL</td><td>2</td><td>≥110*</td><td>2016</td></tr>
<tr><td>DF-31 (CH-SS-10 Mod 1)
Type – ICBM
Fuel type – Solid</td><td>7,000+</td><td>NUCLEAR X 1</td><td>ROAD-MOBILE TEL</td><td>3</td><td>8</td><td>2006</td></tr>
<tr><td>DF-31A (CH-SS-10 Mod 2)
Type – ICBM
Fuel type – Solid</td><td>11,000+</td><td>NUCLEAR X 1</td><td>ROAD-MOBILE MEL</td><td>3</td><td>24</td><td>2007</td></tr>
<tr><td>DF-31A(G) (CH-SS-10 Mod ?)
Type – ICBM
Fuel type – Solid</td><td>11,000+</td><td>NUCLEAR X UNKNOWN</td><td>ROAD-MOBILE TEL</td><td>3</td><td>30</td><td>2017</td></tr>
<tr><td>DF-41 (CH-SS-20)
Type – ICBM
Fuel type – Solid</td><td>12,000+</td><td>NUCLEAR X MULTIPLE</td><td>ROAD-MOBILE TEL (LIKELY SILO IN THE FUTURE)</td><td>3 + PBV</td><td>24</td><td>2020</td></tr>
</table>

*Total number of launchers includes both nuclear and dual-capable versions.
Sources: *The Military Balance 2022*; National Air and Space Intelligence Center; US Department of Defense

Map 3.2: **China's evolving sea-based nuclear deterrent**



NAME	TYPE	RANGE (KM)	FUEL TYPE	NO. OF STAGES	WARHEAD TYPE AND NUMBER	BASING OPTION	NO. OF LAUNCHERS (ESTIMATED)	INITIAL OPERATIONAL CAPABILITY
JL-2 (CH-SS-N-14)	SLBM	7,000+	Solid	3	Nuclear x 1	Type-094 SSBN	72	2015
JL-3 (CH-SS-N-?)	SLBM	10,000+	Solid	3	Nuclear x multiple	Type-096 SSBN and potentially Type-094 SSBN	Unknown	Under development

Sources: *The Military Balance 2022*; National Air and Space Intelligence Center; US Department of Defense

degree of certainty. The first flight tests of the JL-3 from a modified conventional submarine took place in November 2018.[31]

Air-Launched Ballistic Missiles and the PLAAF's Nuclear Role

After decades of largely sitting out the nuclear mission, the PLA Air Force (PLAAF) will play a greater role in China's nuclear force, giving Beijing a strategic triad. Despite the fact that China's early atmospheric nuclear tests were conducted via air-dropping gravity bombs, the PLAAF likely did not field nuclear weapons, suggesting that ground-launched missiles were by far the favoured means of nuclear delivery. A 1971 US Defense Intelligence Agency (DIA) assessment observed, for instance, that 'operational storage sites for nuclear bombs at airfields have not been identified in China'.[32] This assessment was repeated in 1984, but the DIA noted that 'a small number of the nuclear capable aircraft probably have nuclear bombs', despite the lack of evidence of airfield-adjacent weapons storage.[33] A 1993 report for US lawmakers echoed this appraisal, noting that while 'the Chinese Air Force has no units whose primary mission is to deliver China's small stockpile of nuclear bombs', it was possible that 'some units may be tasked for nuclear delivery as a contingency mission'.[34] Exactly the extent to which the US believed the PLAAF would participate in nuclear-delivery missions varied across intelligence assessments over time, but, in general terms, assessments emphasised the ground-based missile force rather than the PLAAF. The possibility of a nuclear mission, however, was never ruled out, which is why, in 2018, the US Department of Defense, in its annual report for US lawmakers on China's military, shared the judgement that the PLAAF had been 're-assigned a nuclear mission', indicating that such a mission may have existed in the past. The US evaluation noted that the 'deployment and integration of nuclear-capable bombers would, for the first time, provide China with a nuclear triad, consisting of ground-, sea- and air-launched weapons. Beijing's choice of nuclear armament for the PLAAF, however, does not appear to incorporate gravity bombs, but rather air-launched ballistic missiles (ALBMs).[35]

In late 2017 and early 2018, US intelligence agencies appeared to solidify the assessment that the PLAAF would soon field an ALBM derived from the DF-21 solid-fuel medium-range ballistic missile. Five tests of such a missile had been conducted by April 2018 and the prototype was designated the CH-AS-X-13.[36] US intelligence officials first referenced the existence of ALBMs in China in 2017, when Lieutenant-General Vincent R. Stewart, a former head of the DIA, said that China was pursuing 'two, new air-launched ballistic missiles, one of which may include a nuclear payload'.[37] The intended carrier for this missile was a modified PLAAF H-6 bomber, the H-6N. The prototype ALBM was first seen by eyewitnesses in China in October 2020 and more public footage emerged in April 2022.[38] This system may be fielded by the mid-2020s. The pursuit of nuclear-capable ALBMs – a first for China – may represent growing concerns about the survivability of its land-based nuclear forces. As a form of hedging against a breakthrough in US counterforce capabilities, including conventional counterforce capabilities, Chinese leaders may see advantages in a nuclear mission for the PLAAF. Additionally, ALBMs could be released from within China to strike regional targets with conventional warheads. Alternatively, the H-6N, which can be refuelled in-flight by a number of PLAAF tankers, could traverse into the Pacific Ocean to potentially hold targets in the continental US at risk of retaliation via nuclear weapons. However, given that these bombers will be based at known, fixed airfields, they may be particularly vulnerable to pre-emptive attack. Authoritative Chinese sources have not acknowledged the existence of these ALBM programmes or the strategic intention behind granting the PLAAF a nuclear mission. No country has ever fielded ALBMs as part of its strategic nuclear forces. During the Cold War, the US nearly deployed the GAM-87 *Skybolt*, but that programme was cancelled.[39] Russia has fielded and employed the nuclear-capable *Kinzhal* (RS-AS-24 *Killjoy*) ALBM in the course of its 2022 war against Ukraine, but this is a non-strategic system.[40] If China proceeds to field a nuclear-capable ALBM for strategic nuclear operations, it will be the first country to do so in the nuclear age.

SINO-RUSSIAN COOPERATION
Russian President Vladimir Putin meets with Chinese President Xi Jinping in Beijing, 4 February 2022. China and Russia are cooperating on developing an early-warning ballistic-missile defence system. CREDIT: Alexei Druzhinin/AFP/Getty Images

Broader Nuclear Modernisation

Beyond delivery systems, China is undertaking a range of nuclear-modernisation activities related to command and control and strategic warning. While details on the precise nature of Chinese modernisation activities related to nuclear command, control and communications (NC3) systems are sparse, the country's leadership accords great significance to robustness and survivability in this area.[41] Much of this emphasis traditionally stemmed from the country's assured-retaliation posture, which meant that national leaders would need to be able to reliably issue valid launch orders to PLA 2nd Artillery Corps bases to carry out retaliatory nuclear operations. The most important modernisation component of China's overall NC3 systems is the addition of new early-warning capabilities. In October 2019, Russian President Vladimir Putin announced that Moscow was 'now helping … Chinese partners create a missile attack warning system'.[42] Since then, details about the precise nature of Sino-Russian cooperation on the development of a missile-warning system are sparse, but they appear to be an important component of Beijing's broader nuclear-modernisation project.[43] Efforts to build such a system and the deployment of at least one warning satellite into orbit have raised concerns in the US that Beijing may be opting for a launch-on-warning posture in the future for its nuclear forces, which could be interpreted by Chinese leaders as consistent with Beijing's long-standing 'No First Use' (NFU) declaratory policy. The US assesses that China has, since 2017, conducted exercises involving a launch-on-warning posture.[44] A possible Chinese shift towards launch-on-warning remains indeterminate, but could become increasingly likely as Beijing's new silo fields in western China are completed. According to official Chinese statements, China maintains its nuclear forces in a 'state of moderate readiness' in peacetime and has plans to raise alert levels in a crisis.[45]

Regional Ballistic and Cruise Missiles

Beyond its strategic nuclear missiles, the PLARF operates a significant and growing inventory of regional ballistic and cruise missiles, including nuclear-capable theatre-range ballistic and hypersonic boost-glide missiles. Theatre-range is defined as any system in the sub-5,500 km-range category.

Nuclear-Capable Regional Missiles

Nuclear-capable theatre-range missiles in the PLARF's inventory include two variants of the DF-21 solid-fuel medium-range ballistic missile, the DF-21A (CH-SS-5 Mod 2 and the CH-SS-5 Mod 6); the dual-capable DF-26 (CH-SS-18), which features field-swappable conventional and nuclear warheads; and possibly the DF-17 (CH-SS-22) medium-range hypersonic boost-glide vehicle.[46] Estimates of the total inventory

Map 3.3: **PLA Rocket Force missile bases and brigades**

Sources: *Asia-Pacific Regional Security Assessment 2022*

NOTE: MUCD = Military Unit Cover Designator

of China's theatre-range missile forces vary, but the PLARF is thought to operate more than 900 intermediate-range and medium-range ballistic missiles with some 450 available launchers; this includes dual-capable and conventional-only missiles, like the DF-16.[47] This category, in particular, has seen significant growth in the last five years, primarily due to a rapid expansion in the inventory of DF-26 missiles available to the PLARF. The DF-26 is notably unique among all known Chinese missile systems for featuring an ability for its operational crews to rapidly swap between conventional and nuclear warheads in the field.[48] A clamshell cover attached to the system's TEL – a unique feature among all known and fielded PLARF systems – offers crews access to the missile's warhead.[49] Beyond the three nuclear-capable systems described above, some sources ascribe a nuclear role to the DF-15 (CH-SS-6) SRBM, but this is based on a 1993 assessment by the CIA that China had 'almost certainly' developed a warhead for this missile.[50] More recent US assessments, such as the US Department of Defense's 2021 annual report for US lawmakers on Chinese military capabilities and the 2020 report of the US Air Force National Air and Space Intelligence Center, describe the DF-15 as a conventional SRBM.[51] The non-nuclear status of the DF-15 would indicate that China does not operate any nuclear-capable SRBMs. Beijing also is not known to assign a nuclear-weapons delivery role to any of its ground-launched cruise missiles.

Non-nuclear Regional Ballistic and Cruise Missiles

Beyond the above-described nuclear-capable systems, the PLARF operates a wide variety of ground-launched conventional ballistic and cruise missiles. These include missiles across the short- (300–1,000 km), medium- (1,000–3,000 km) and intermediate-range (3,000–5,500 km) categories. Short-range, ground-launched ballistic missiles include the 600 km-range DF-11 (CH-SS-7), the 700 km-plus-range DF-16 (CH-SS-11) and the 850 km-plus-range DF-15 (CH-SS-6); each of these missiles exists in multiple modifications, with a variety of conventional warheads available.[52] The DF-17 hypersonic boost-glide vehicle-capable system and the dual-capable DF-26 are also included in this category. The DF-17 may replace certain older Chinese SRBM units.[53] The US Department of Defense has pointed to the possible development of a new intermediate- or low-intercontinental missile known as the DF-27, but little else is known about the nature of this system, including whether it will be dual-capable.[54] Beyond these, Beijing can produce numerous ballistic missiles in the close-range (sub-300 km-range) category. These include, in order of increasing range, the WS-22, BRE7/*Fire Dragon* 40, GR1/*King Dragon* 60, BRC-3, A100-111, A100-311, BRC-4, BRE-2, BRE-3, B611, WS-2 (and variants), WS-3, B611M, A300, WS-64, BP-12A, M20 and BRE-8.[55] One notable, newer ship-launched system, known possibly as the YJ-21, was revealed to have been tested from a Type-055 cruiser in April 2022.[56] Details about this missile remain scarce, but

Figure 3.2: **PLARF conventional ballistic-missile inventory**

Name	Type	Fuel type	Range (km)	Warhead type and number	Basing option	Number of stages	Number of launchers (estimated)	Initial operational capability
DF-11A (CH-SS-7 Mod 2)	SRBM	Solid	600	Conventional	Road-mobile TEL	1	108	1992
DF-15A (CH-SS-6 Mod 1)	SRBM	Solid	600	Conventional	Road-mobile TEL	1		1991
DF-15B (CH-SS-6 Mod 3)	SRBM	Solid	725+	Conventional	Road-mobile TEL	1	≥81	2009
DF-15C (CH-SS-6 Mod 2)	SRBM	Solid	850+	Conventional	Road-mobile TEL	1		2013
DF-16 (CH-SS-11 Mod 1/2)	SRBM	Solid	700+	Conventional	Road-mobile TEL	2	36	2011
DF-17 (CH-SS-22)	MRBM (HGV)	Solid	Unknown	Conventional	Road-mobile TEL	1	24	2020
DF-21C (CH-SS-5 Mod 4)	MRBM	Solid	1,500+	Conventional	Road-mobile TEL	2	24	2006
DF-21D (CH-SS Mod 5)	MRBM (ASBM)	Solid	1,500+	Conventional	Road-mobile TEL	2	30	2006
DF-26 (CH-SS-18)	IRBM	Solid	3,000+	Dual-capable (nuclear x 1)	Road-mobile TEL	2	≥110*	2016
DF-26B (CH-SS-18 Mod ?)	IRBM (ASBM)	Solid	4,000	Conventional	Road-mobile TEL	2		2016

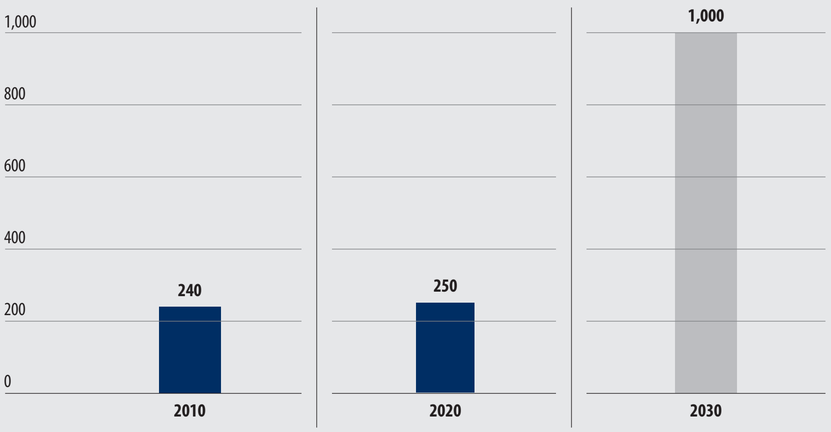
*Total number of launchers includes both nuclear and dual-capable versions.

Sources: *The Military Balance 2022*; National Air and Space Intelligence Center; US Department of Defense its existence underscores the diversification under way in China's missile inventory. Ground-launched cruise missiles include the approximately 1,500 km-range subsonic DH-10/CJ-10 (CH-SSC-9) and the approximately 2,000 km-range DF-100/CJ-100 (CH-SSC-13).[57]

China also operates two ASBMs: the DF-21D and a variant of the DF-26 with an unknown official designation. The systems – often referred to as 'carrier-killer' missiles – have been undergoing testing, but it remains uncertain whether the complex kill chain necessary for ASBMs has been fully validated. US officials confirmed that China had attempted the first test of its ASBMs against a moving live-ship target in November 2020, but did not confirm whether that test succeeded.[58] The 2020 testing involved both the DF-21D and the ASBM variant of the DF-26. Developmental efforts relating to China's ASBM programmes appear to be ongoing. Chinese engineers built a rail-mounted mobile target in the rough shape of a US *Gerald R. Ford*-class aircraft carrier in the Taklamakan Desert between March and April 2019; this facility saw renewed activity after the attempted ASBM tests in 2020, which could indicate ongoing work to improve the performance of these systems and to close the ASBM kill chain in general.[59]

Apart from the land-based ballistic- and cruise-missile inventory stewarded by the PLARF, the PLAN and PLAAF operate a diverse array of non-ballistic missile systems. These include a range of ship- and air-launched cruise-missile designs. Notable missile systems in this category include the YJ-12 supersonic anti-ship cruise missile (ASCM), which can be accommodated on both surface warships and H-6G/H-6J strategic bombers, and the YJ-18A, a newer ASCM deployed on surface ships and submarines alike.[60] A ground-launched variant short-range supersonic ASCM, the YJ-12B, has reportedly been fielded on some of China's artificial-island outposts in the disputed South China Sea.[61] Another system of note is the CJ-20 long-range air-launched cruise missile, which can be carried by PLAAF H-6K bombers. The US Department of Defense assesses that the H-6K-launched CJ-20 would give the PLAAF 'the ability to engage U.S. forces as far away as Guam'.[62] Finally, China is in the process of testing and evaluating ship-launched hypersonic cruise missiles and submarine-launched land-attack cruise missiles.[63] US intelligence has underscored that China has made important advancements with regard to scramjet-engine development for use in hypersonic cruise missiles.[64]

Figure 3.3: **China's growing nuclear-warhead stockpile, 2010–30**



Sources: IISS analysis; *The Military Balance 2022*; National Air and Space Intelligence Center; US Department of Defense

Drivers of China's Nuclear Force Build-up

Until 2020, authoritative public estimates, including by Western intelligence agencies, assessed that the quantitative size of China's nuclear forces remained largely in line with their historically lean nature, but also that Beijing's stockpile of nuclear warheads could double by 2030.[65] In 2021, the US Department of Defense appraised in its annual report to Congress that China was pursuing a significant quantitative expansion of its warhead stockpile. Though Chinese officials have not commented on these assessments – including to repudiate them – as recently as October 2020 senior Chinese diplomats appeared to reject the notion that Beijing might expand its nuclear forces. For instance, Fu Cong, Director General of the Chinese Ministry of Foreign Affairs' Department of Arms Control, pushed back on a commentary written by the editor-in-chief of the CPC-linked *Global Times* that called for a thousand-warhead nuclear force. In doing so, Fu underscored that the commentary was the 'opinion of a journalist' and that the idea 'is not endorsed by anybody', with 'anybody' in this context meaning presumably Chinese senior leadership.[66] At the time, China was under substantial pressure from the Trump administration to participate in a trilateral strategic arms-reduction process with Russia and the US, which it adamantly refused to do. Expanding on the issue of the quantity of China's nuclear force, Fu noted that 'for the purpose of maintaining the effectiveness of the Chinese nuclear deterrence, it is important that China maintains certain degree of ambiguity in terms of its numbers'.[67]

There are several internal and external drivers of China's qualitative modernisation and quantitative force expansion. The set of drivers influencing Beijing's nuclear-force-structure changes may be meaningfully different than those prompting continued conventional modernisation, however. On the nuclear side, a set of long-running issues, such as concerns about US missile-defence capabilities and conventional counterforce capabilities, continue to bear relevance.[68] However, these drivers have been relevant since at least the first term of the George W. Bush administration (particularly after the US decision to leave the 1972 Anti-Ballistic Missile Treaty was announced). As such, they cannot fully explain Beijing's sudden turn towards pursuing a significantly larger nuclear force, which appears to have taken hold a few years after the 19th National Congress of the Chinese Communist Party in 2017. Since this period, there has been no meaningfully qualitative or quantitative breakout by the US with regard to missile defence or conventional counterforce capabilities. On the latter, in particular, the US, since the Obama administration, has de-emphasised early designs of a conventional prompt *global* strike in favour of theatre-range conventional-strike capabilities; this has continued particularly in the post-INF Treaty environment and with the broader US focus on developing hypersonic weapons.[69] The most notable strategic shift that has coincided with Beijing's changing perspective on the appropriate size of its nuclear arsenal is the dramatic decline in US–China relations that began in 2017 and accelerated under the administration of former US president Donald Trump. Chinese leaders may have started to perceive a heightened probability of general conflict with the US and may thus calculate that a more robust nuclear deterrent may be necessary to induce caution in the US and in the way it may choose to escalate. In particular, as the conventional balance of power in the Indo-Pacific, particularly within the Second Island Chain, shifts in China's favour, Beijing may fear that the US would contemplate offsetting this inferiority with resort either to the actual first use of nuclear weapons or to threats of nuclear first use to coercive ends. This perception could be reinforced by the fact that US policymakers saw utility in offsetting the Soviet Union's conventional quantitative advantages with resort to early nuclear use against conventional forces during the Cold War. One American analyst who would go on to contribute to the Trump administration's defence policymaking suggested in 2019 that the US 'would benefit from having limited nuclear options that could heavily damage a Chinese invasion flotilla designed to assault U.S. allies in the Western Pacific'.[70] Such views could have contributed to a shift in Chinese threat perceptions and in prompting an interest in better managing escalation should the US choose to deliberately resort to nuclear use. The general rise in the Chinese leadership's apparent threat perceptions coheres with accounts from the final months of the Trump administration – particularly US Chairman of the Joint Chiefs of Staff General Mark Milley's assertion that the US had reason to believe 'the Chinese were worried about an attack by the U.S.'.[71]

Defensive logics for Beijing's build-up, however, cannot be ruled out. For instance, given China's continuing assertion of an NFU policy and traditional emphasis on assured retaliation, a larger nuclear force – one less impervious to both conventional and nuclear counterforce attack – could discourage a turn towards contemplating first use. Similarly, contrary to some existing assessments, a larger Chinese nuclear force could actually dissuade the pursuit of a launch-on-warning posture, which is traditionally associated with states that perceive vulnerability at the strategic level. China's transition, however, to a larger force will take time – particularly with regard to fissile-material production. As an interim measure, Beijing may contemplate the adoption of a launch-on-warning posture until it has what its leaders perceive to be a sufficiently robust assured-retaliation capability.

ANTI-SHIP BALLISTIC MISSILES
China's DF-21D anti-ship medium-range ballistic missile. CREDIT: Greg Baker/AFP/Getty Images

There are, however, competing hypotheses for China's nuclear-force-structure shifts and these will persist until Beijing opts to offer greater transparency about its intentions.[72] Beyond heightened perceptions of a US threat to China's interests, certain observers in the US see less benign intentions behind Beijing's build-up, particularly concerning a potential war of choice across the Taiwan Strait to pursue unification.[73] For decades, Chinese leaders have been aware of the vulnerabilities associated with their reliance on a lean nuclear force, but they have opted against pursuing notable quantitative growth.

Effective Counter-attack: A Moving Target

Popular descriptions of China's nuclear strategy correctly acknowledge the historically lean nature of China's force size but ascribe this to an apparent choice by Chinese leaders to pursue a policy of 'minimum deterrence' or a variant thereof.[74] This is a misnomer. Instead of 'minimum deterrence', China's nuclear policy, since its maturation during the mid-Cold War, has ossified around the notion of 'effective counterattack', or 'counterattack in self-defense' paired with the 'limited development' of nuclear weapons.[75] The aspirational description of China's nuclear force was 'lean and effective'.[76] This choice was borne of early considerations by China's leaders that the role of nuclear weapons was, broadly, firstly to deter nuclear attack, and secondly to deny an adversary (the US) the opportunity to engage in nuclear coercion. The latter concern was particularly acute for China's first paramount leader, Mao Zedong, during the final months of the Korean War and the Taiwan Strait Crises of 1954–55 and 1958.[77] The concern during this time was that the US could compel and coerce China to accept unfavourable outcomes by brandishing its nuclear weapons – a capability for which the then-young People's Republic had no answer.

NUCLEAR TESTING
China's first nuclear weapons test at Lop Nur, October 1964. CREDIT: Pictures from History/Universal Images Group/Getty Images

The first objective of China's nuclear strategy – deterring nuclear attack – was communicated immediately after its first nuclear test in October 1964.[78] China's official Xinhua News Agency carried a statement on China's nuclear test, which noted that 'the Chinese Government hereby solemnly declares that China will never at any time and under any circumstances be the first to use nuclear weapons'. This constituted the world's first – and only remaining – pledge of unconditional NFU.[79] This seeded the basic principle of Chinese thinking about nuclear deterrence: absorbing the enemy's first use with a force sufficiently survivable to effectively assure retaliation, or counter-attack. The reason this posture was not akin to 'minimum deterrence' was because the nature of the force required to accomplish this objective was not fixed, in either quantitative or qualitative terms. What was necessary for 'effective counterattack', in other words, changed as the adversary's capability to threaten the survivability of China's second strike changed. The reason for the popularity of the 'minimum deterrence' idea was that *in practice* Chinese leaders believed that despite a number of changes to their security environment, retaliation for an adversary's attack could be assured with a small number of nuclear weapons as these could still credibly threaten damage in excess of what the adversary would deem acceptable. To render the emphasis on nuclear counter-attack and NFU credible, China took practical steps, such as storing warheads separately from their delivery systems and exclusively conducting exercises for the PLA 2nd Artillery Corps and PLARF that simulated missile-launch operations in the aftermath of a nuclear attack on China. As China's general military power and fortunes in the international system grew, particularly in the first two decades of the twenty-first century, this became a major point of contrast with the US and Russia, each of which maintained a significantly larger operational nuclear arsenal.

As discussed above, ongoing changes to China's nuclear-force structure as part of its modernisation are notable for what they suggest about the beliefs of China's leaders about the role of nuclear weapons today. The pursuit of new early-warning capabilities and theatre-range, precise nuclear systems as well as a considerable expansion of the land-based missile force suggest possible changes in five areas:

- Firstly, Chinese leaders may now broadly have greater concerns than in the past about the level of damage that should be credibly threatened in any retaliatory strike, in order to deter the adversary's first use.
- Secondly, Chinese leaders have reassessed their traditional wariness about entering into a quantitative arms race – perhaps due to a broader assessment that China is continuing to rise while the US is faltering, which has become a theme in internal propaganda during the coronavirus pandemic in particular.[80] Older concerns were borne of an assessment that the Soviet Union's decision to pace the United States' nuclear pursuits during the Cold War contributed to its decline and demise.
- Thirdly, although not exclusively responsible, organisational reform within the PLA since 2015 may have elevated the inputs of the military on these matters in ways that had been previously limited. This is difficult to substantiate with open sources, but the growing prominence of the PLARF under Xi since 2015 suggests this may be difficult to rule out.
- Fourthly, the diversification of launch systems and basing modes – including the new silo fields and the adoption of an ALBM possibly for strategic nuclear retaliation – suggest some interest in technological hedging against the possible failure of certain basing modes. The expansion in China's nuclear forces may be broadly borne of an effort to comprehensively hedge what was on track to become an overreliance on ground-based road-mobile missile launchers. While these launchers are survivable in practice, Chinese leaders may fear future breakthroughs in US conventional long-range strikes and related enabling capabilities that could blunt the survivability of this force.
- Fifthly and finally, given the broader emphasis by Xi on the need for China to attain a 'world-class military', the ongoing build-up may be motivated by prestige considerations.[81]

None of these explanations fundamentally or necessarily suggest a break with Beijing's long-standing NFU policy or assured-retaliation posture; rather, they underscore the extent to which that which is considered effective for assuring retaliation changes amid broader political and technological shifts in China's strategic environment.

Post-INF Missile Environment in Asia and China's Response

Beyond responding to concerns about the US, Chinese strategists are contending with the disappearance of a significant arms-control pillar that shaped their security environment: the end of the Treaty Between the United States of America and the Union of Soviet Socialist Republics on the Elimination of Their Intermediate-Range and Shorter-Range Missiles, also referred to as the INF Treaty. In August 2019, the US ceased to be a party to the 1987 INF Treaty, citing Russian non-compliance.[82] The treaty, which saw the dismantling of all ground-launched IRBMs and cruise missiles between the US and the Soviet Union in the course of its implementation, had barred either side from developing, testing or fielding any such missiles with ranges between 500 and 5,500 km.[83] In the lead-up to the Trump administration's decision to withdraw from the treaty, notable constituencies within the US, including the United States Pacific Command (now the United States Indo-Pacific Command), had articulated concerns about a perceived imbalance in US and Chinese missile capabilities in the Pacific, partly due to the limitations imposed on the US by the INF Treaty.

While China's inventory of ground-launched ballistic and cruise missiles ballooned during the 32-year period of US participation in the INF Treaty, the United States' exit from the treaty is largely seen by Chinese officials and strategic thinkers as a negative development for Beijing's security. The expiration of treaty constraints on the US stands to qualitatively change the types of capabilities that the PLA would need to consider in its military planning. Even if the US is poorly poised to match, in quantitative terms, China's considerable inventory of missiles in the INF-proscribed range classes, the uncertainty of the post-INF Treaty environment is not seen favourably in Beijing. In 2019, after the US had withdrawn from the treaty, official Chinese Ministry of Defense spokesperson Senior Colonel Wu Qian noted that China would respond to any future US deployments of ground-launched missiles to the region. The spokesperson noted that US 'arbitrary actions are bound to damage the security interests of the regional countries, threatening regional peace and stability'.[84]

Chinese officials reacted negatively to the US withdrawal from the treaty and drew attention to two subsequent US missile tests. Two weeks after the US withdrawal from the treaty took effect in August 2019, the US tested a cruise

GUAM
Andersen Air Force Base located on Guam might be a potential site for US ground-launched missiles in the Indo-Pacific. CREDIT: Virgilio Valencia/AFP/Getty Images

missile from a ground-based Mark 41 Vertical Launch System to 'its target after more than 500 kilometres of flight', and again, in December 2019, tested a ground-launched IRBM which 'terminated in the open ocean after more than 500 kilometres of flight', according to the US Department of Defense.[85] A spokesperson for the Chinese Ministry of Foreign Affairs criticised these tests as evidence that the US was seeking to 'free itself to develop advanced missiles and seek unilateral military advantage'.[86] These tests were effectively notional technology demonstrators, enabled through the use of rapid-prototype engineering led by the Pentagon's Strategic Capabilities Office.

As described elsewhere in this chapter, the trajectory of China's missile-force development since the late 1980s has been nothing short of meteoric, with Beijing today possessing a vast and diverse arsenal of conventional and dual-capable theatre-range missiles. The prospect of a symmetrical US response, while perceived negatively in Beijing, may be borne of concerns that a more robust American ground-launched long-range precision-strike capability – particularly one with a degree of persistence, if forward-deployed west of the Second Island Chain – could blunt Beijing's capability to project force in its near seas, including in the Taiwan Strait. America's plans post-INF Treaty remain indeterminate, even though US lawmakers have appropriated funds to support the development of a range of new missile systems that would have otherwise been proscribed under the INF Treaty.[87] Critically, with the exception of the US territory of Guam, which is more than 3,000 km from the Chinese mainland, Washington has no US territory upon which it can freely base new ground-launched missiles. Of the US missiles known to be under development in the post-INF environment, the longest-range weapon, the US Army's Long-Range Hypersonic Weapon (LRHW), has a disclosed range of 'greater than 2,775 km' – which may be insufficient to reach mainland China-based targets from Guam unless the LRHW's maximum range is greater than this.[88] The US treaty allies that might host new US missiles – Australia, Japan, the Philippines or South Korea – may or may not be willing to host such missiles today, but China likely sees this as subject to change in the absence of a legal ban on US production and deployment of these types of missiles.

Despite frequent Chinese criticisms of the US decision to leave the INF Treaty and to build new missiles, Beijing has not articulated a concerted policy response. Similarly, China's force structure has remained largely consistent with the trajectory exhibited before the United States' treaty withdrawal, with the exception of the substantial expansion in the strategic nuclear force. This could point to some concern in China that conventional, theatre-range US missiles, if deployed to the First Island Chain, could pose a prompt counterforce challenge to its nuclear force, demanding a quantitative expansion to improve survivability. In anticipation of greater missile threats more generally in the region, including from US allies such as Australia, Japan and even South Korea, Beijing is investing in a range of missile-defence systems, including mid-course missile-defence systems capable of engaging relatively long-range ballistic missiles.[89] The PLAN will field mid-course interceptors on the Type-055 guided missile destroyer, which the US Department of Defense has interpreted as likely forming the basis for a 'forward deployed missile defense' capability.[90] More generally, China can be expected to continue developing its integrated air-defence system, with a particular focus on coastal area defence and point defence of critical military bases. The PLA's long-range surface-to-air missile (SAM) systems may also offer defence against cruise missiles, which will continue to form a significant component of the non-ground-based US conventional-strike capability within the Second Island Chain. Systems like the HQ-9 (CH-SA-9), HQ-9B (CH-SA-21) and the Russian-origin S-300PMU (RS-SA-10 *Grumble*), S-300PMU1/PMU2 (RS-SA-20 *Gargoyle*) and newer S-400 (RS-SA-21 *Growler*) SAMs will cover this class of threats. The US Department of Defense also assesses that China plans to fill out a 'multi-tiered missile defense' architecture with a kinetic kill vehicle for exo-atmospheric mid-course defence.[91]

The Prospect for Strategic-Stability Dialogues

While there is no monolithic interpretation within China of strategic stability (just as in the US), the broad contours of how Beijing views the concept are both compatible with and divergent from the traditional Cold War era definitions that emphasise crisis stability and arms-race stability as the two subsidiary conditions necessary for strategic stability. In the traditional understanding, a crisis can be considered stable when no party has an incentive to resort to military use first, or to resort to the first use of nuclear weapons. Similarly, arms-race stability describes the absence of incentives for any party in a competitive relationship to seek advantage by building additional military capability. The most important divergence concerns the breadth of what Chinese strategic thinkers have considered to be relevant for strategic stability, which is broader than matters pertaining to nuclear weapons alone and concerns 'political-military relations more generally'.[92] Strategic stability, in this way, can encompass a broader balance of power between two countries, encompassing all elements of national power.

Despite this apparent divergence, consideration of traditional strategic-stability issues has informed China's pursuit of nuclear weapons; its adoption of an assured-retaliation posture was borne of concerns about resisting nuclear coercion (especially after the Second Taiwan Strait Crisis) and an interest in deterring nuclear attack. While Chinese leaders may never have been fully satisfied with the level of survivability of their second-strike forces, they generally viewed a lean nuclear force as promising sufficient levels of damage to deter any adversary from employing nuclear weapons against China.[93] Despite US scepticism about China's intentions and NFU-declaratory policy, these measures were generally conducive to engendering broad strategic stability between the two countries. Meanwhile, in the last two decades, Chinese scholars, experts and officials have described the posture and policy of the US – with regard to nuclear weapons, missile defence and certain conventional weapons – as undermining strategic stability. Particular areas of Chinese concern have been US homeland-based and forward-deployed theatre missile-defence systems, long-range conventional precision-strike weapons and the refusal of successive US administrations to rule out the first use of nuclear weapons.[94] More recently, Chinese officials have pointed to the Trump administration's decision to abrogate and withdraw from a number of international treaties as detrimental to broader strategic stability – in particular the INF Treaty, as described above.[95]

Prospects for US–China dialogue on strategic stability have been dim for more than a decade and show few signs of improving. The Biden administration appears to recognise the seriousness of the shift in China's nuclear posture and has sought to engage Beijing on the matter. Nuclear weapons were among the issues addressed at a virtual November 2021 meeting between US President Joe Biden and Xi. Kurt Campbell, the Indo-Pacific coordinator on Biden's National Security Council, has said these efforts remained in their 'early stages'.[96] Jake Sullivan, the Advisor to the President on National Security Affairs (APNSA), said that Biden and Xi 'agreed that we would look to begin to carry forward discussions on strategic stability'.[97] While some press reporting interpreted Sullivan's comments to imply that such discussions were bound to take place, the APNSA was indicating that the matter had merely been raised; the degree of China's support for such talks appears to remain low.[98] Qin Gang, the Chinese Ambassador to the US, rejected these descriptions of nuclear-related discussions between Biden and Xi in an interview more than a month after the summit, underscoring instead that the US should 'take the prime responsibility to axe its nuclear arsenal and take the lead'.[99] In January 2022, the US and China, along with France, Russia and the United Kingdom, endorsed a joint declaration of the five-party Treaty on the Non-Proliferation of Nuclear Weapons states (the P5) on 'Preventing Nuclear War and Avoiding Arms Races'.[100] This, however, is widely seen as lacking in substantive impact, and has resulted in no meaningful US–China exchanges on nuclear issues. P5 dialogue on nuclear doctrine has also been seen as being non-substantive, with both China and Russia perceived to be obfuscatory in their public doctrinal declarations. Non-governmental tracks for dialogue on nuclear issues have been diminished in recent years as well – partly as a result of the coronavirus pandemic.

In late 2020, under pressure from the Trump administration to participate in trilateral arms-control talks, the head of the Chinese Foreign Ministry's Department of Arms Control and Disarmament noted that China was 'open to dialogues' with the US on a range of issues. He proposed that these talks could cover strategic stability, nuclear-risk reduction, no first use and missile defence, adding that there could be 'very meaningful discussions'.[101] Given current political dynamics within China, where matters of foreign and security policy appear to be driven exclusively by the highest levels of CPC political decision-making, it is unclear if these views are shared by Xi and those closest to him. Based on the experience of the Biden administration, it does not appear that China is enthusiastic about the prospect of such talks. Given that currently available evidence suggests that China's modernisation and force-structure expansion are ongoing and, in the case of its silos, in a relatively early phase, it may be the case that Chinese leaders will see reason to participate only once this expansion is complete.

While substantive talks on formal bilateral arms-control measures may depend on China reaching a deterrence equilibrium with the US, or at least a steady state of sorts with regard to its ongoing modernisation, the US and China should seek to establish an open dialogue on nuclear matters and strategic stability promptly. Both Beijing and Washington acknowledge the difficult streak in their bilateral relations and each side may perceive the risk of conflict to be greater now than at any time in the post-Cold War era. In this environment, a general, high-level exchange on the role of nuclear weapons in each country's national strategy could prove useful by encouraging important official-level relationships and building habits of dialogue. This dialogue could include establishing a fundamental shared understanding on basic questions, such as the purposes of arms control and the meaning of strategic stability. Both sides could also cover issues pertaining to non-traditional domains, including space and cyberspace. Beijing has a set of issues that it would see as more salient in such a dialogue, such as missile defences, while Washington would have its own list.[102] Despite divergences, exploratory talks could nonetheless help build shared understanding about issues that could be primed for expansion in a potential future formal process of arms control and those that are less suited for limitations.

Notes

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2 The US intelligence community describes short-range missiles as those with ranges between 300 and 1,000 km, though the INF Treaty defines these missiles as those with ranges between 500 and 1,000 km. The US intelligence community considers medium-range missiles as those with ranges between 1,000 and 3,000 km and intermediate-range missiles as those with ranges between 3,000 and 5,500 km. The INF Treaty defined all missiles with ranges between 1,000 and 5,500 km as intermediate-range missiles.

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CHAPTER FOUR

Russia

Russian President Vladimir Putin's decision to invade Ukraine in February 2022 fundamentally reshaped European security. In this environment of entrenched hostility between the United States/NATO and Russia, Moscow will perceive a yet-greater threat from an expanding Western alliance now on its doorstep. It will now also have to contend with its diminished ground forces and loss of geopolitical status, as well as a potentially prolonged economic and technological isolation from the West. All of these changes will have implications for the US and NATO allies.

Russia has an extensive and diverse set of missile capabilities. These are at the heart of Moscow's ability to deter its adversaries and execute war-fighting plans. Its arsenal of intercontinental ballistic missiles (ICBMs), submarine-launched ballistic missiles (SLBMs) and air-launched cruise missiles (ALCMs) provides a deterrent to the United States/NATO. Theatre-range missiles are primarily intended for deterrence of and use in regional contingencies. The dual-capable functionality of many missile systems gives the Russian armed forces a versatile range of capabilities for both non-nuclear and nuclear missions.

Over the last two decades, Russia has modernised its nuclear forces, the heart of its strategic deterrence system, seeking to improve their resilience and ability to hedge against a US technological breakthrough in missile defence. It has also developed a variety of conventionally armed precision land-attack missiles intended to support deterrence, as well as for war fighting. These allow the Russian military to target adversaries' critical infrastructure with an aim to eventually extend the conventional phase of a conflict with NATO.

Since the signing of the US–Russian New Strategic Arms Reduction Treaty (New START) in 2010, Moscow has stubbornly resisted Western entreaties on limiting its non-strategic nuclear weapons (NSNWs), a bet that is likely to pay dividends in the wake of its invasion of Ukraine. Before the war, Russia and the US sought to discuss a basket of strategic-stability issues as part of a bilateral dialogue process aimed at crafting a new arms-control agreement. This process, however, was halted by the Russia–Ukraine war, and the prospect of talks restarting any time soon appears to be remote.

Key takeaways

MODERNISATION

Russia will continue to modernise its strategic nuclear forces as per its plans, although some equipment timelines and deliverables will likely be delayed due to long-standing challenges.

NON-STRATEGIC NUCLEAR WEAPONS

Moscow's habitual resistance to Western entreaties on limiting its non-strategic nuclear weapons is likely to pay dividends in the wake of its invasion of Ukraine, given the deterioration of Russia's conventional military capabilities.

REDUCED INVENTORY

The Russian armed forces have likely diminished their stockpile of conventional precision-guided munitions, evidenced by their use of older systems in secondary attack modes and through the procurement of foreign equipment.

WAR IN UKRAINE

Russia's invasion of Ukraine in February 2022 will likely present challenges to Moscow's modernisation plans for its armed forces, even though the war does not yet appear to have shifted the focus of the SAP-2033 – at least rhetorically.

ARMS CONTROL

The prospects for future nuclear-arms control are challenging as the Russia–Ukraine war has imposed considerable political and moral pressure on the Biden administration to refrain from negotiations and from normalising relations with Russia.

There are four areas of focus: Russian deterrence concepts that provide the context for its missile capabilities; Russian approaches to nuclear weapons and capabilities across key services and forces; implications of the Russia–Ukraine war, including for the Russian defence industry; and strategic-stability and arms-control issues.

Russian Deterrence Concepts

For several decades, Russian military planners have assumed that the initiation of a large-scale conflict against Russia was unlikely.[1] However, an armed conflict or a local war, which could also begin as domestic instability in Russia, could quickly escalate to a regional or a large-scale war. If deterrence fails, and Russia finds itself pitted against a conventionally superior nuclear peer, Russia's decision-makers believe it will need to prepare to take decisive actions in the initial period of war.[2]

The Russian political and military leadership has articulated a comprehensive system of strategic deterrence that brings together non-military and military means for deterrence, escalation management and war termination.[3] Strategic deterrence encompasses a suite of nuclear and non-nuclear capabilities. Strategic, non-strategic and 'novel' nuclear systems (such as Russia's nuclear-armed hypersonic boost-glide vehicle (HGV) *Avangard* (RS-SS-19 *Stiletto* Mod 4)) provide nuclear deterrence. Non-nuclear deterrence, in turn, is carried out through a variety of capabilities, including ground-launched short-range ballistic missiles (SRBMs) and ALCMs with conventional warheads.

Russia's strategic nuclear-retaliatory potential relies primarily on ICBMs, with silo-based ICBMs instrumental in so-called *otvetno-vstrechnyi udar* (retaliatory-meeting strikes or, in essence, launch on warning) and mobile ICBMs and nuclear-powered ballistic-missile submarines (SSBNs) central to *otvetnyi udar* (retaliatory strikes or, in essence, launch under attack).[4] The strategic nuclear forces are exercised periodically as a whole and there are frequent drills conducted across divisions. These forces need to be able to inflict certain 'assigned' levels of damage on adversaries' military-economic targets that they will find 'unacceptable'.[5] Russia has an extensive variety of dual-capable systems. NSNWs, owing in part to their cost-effectiveness, play important regional deterrent roles and help with signalling, escalation management and, if deterrence fails, war fighting.[6]

Following the collapse of the Soviet Union and the hollowing out of Russia's air and air-defence forces in the 1990s, NSNWs took on greater importance as Moscow's primary response to the prospect of a massed Western aerospace attack on critical targets in Russia. However, Russian officials have suggested a desire to reduce their reliance on NSNWs and concurrent efforts to recapitalise air defence also support this aim.[7] Due to an understanding that nuclear threats may not be credible in smaller-scale and local conflicts, the Russian military has sought to develop more credible deterrence options. These include conventional precision strike, improved air and missile defence (IAMD) and other non-nuclear capabilities that could, if scaled, impose costs on an adversary. They could also help the Russian armed forces disorganise their opponents' ability to effectively operate military forces early in the fight.[8] Over time, the development of these capabilities could also contribute to long-standing efforts to extend the duration of a conventional phase of a regional (US/NATO–Russian) war.

Conventional precision-strike systems have grown in importance in Russia's notions of fighting local wars, as well as in managing the escalation of and war fighting in regional and large-scale conflicts. These systems enable attacks on adversaries' critical infrastructure for operational and psychological ('deterrent damage') effects, including as part of a special strategic operation.[9] Prospective operational concepts suggest tighter integration between conventional and nuclear weapons, potentially as part of a strategic deterrent-forces operation that relies on conventional precision strike and limited nuclear employment.[10]

DETERRENCE
Chief of the General Staff of the Russian Armed Forces Valery Gerasimov, Minister of Defence Sergei Shoigu and President Vladimir Putin meet in Moscow, 27 February 2022. CREDIT: Alexey Nikolsky/Sputnik/AFP/Getty Images

Authoritative Russian military thinkers linked to Russia's General Staff have articulated Russia's deterrence system as operating with three sets of capabilities: strategic nuclear weapons, NSNWs and strategic non-nuclear weapons.[11] Effective and stable nuclear deterrence, they posit, is only possible with the foundation of a credible non-nuclear deterrent. In turn, non-nuclear deterrence capabilities, such as conventionally armed cruise missiles, may play important roles at all levels of conflict: local (Ukraine), regional (Russia–US/NATO) and large scale (Russia–US/NATO and its allies). 'The traditional nuclear deterrence mechanism, supplemented by strategic non-nuclear capabilities, counters major nuclear and non-nuclear threats at the global and regional levels. At the same time, strategic non-nuclear capabilities are viewed as a flexible tool to counter threats, including local non-nuclear threats to the military security of Russia and its allies, as argued by Russian analysts.[12]

Much like the Soviet Union, Russian military planners harbour concerns about the survivability of its strategic nuclear forces in the future. Technological developments of particular concern include increases in the United States' ability to track mobile ICBMs, as well as to conventionally destroy or intercept them.[13] This comes from a conviction that the US is pursuing military superiority and seeks to get out of the US–Russian relationship of 'mutual vulnerability'. Coupled with the political, military and technological uncertainty in the strategic environment, these concerns drive certain Russian choices about its nuclear forces.

Two decades ago, when the US abandoned the 1972 Anti-Ballistic Missile (ABM) Treaty, Russia was faced with the possibility of a breakout in US missile defence that it perceived would adversely affect its second-strike capabilities. To hedge for this eventuality, Russia prioritised the development and procurement of asymmetric systems, some of which may have been revived Soviet ideas to counter the US Cold War Strategic Defense Initiative.[14]

ARMS CONTROL
US president Barack Obama and Russian president Dmitry Medvedev shake hands after signing New START. CREDIT: Stringer/Getty Images

In March 2018, Putin unveiled a number of novel systems designed to evade and penetrate US missile defences. These included *Burevestnik* (RS-SSC-X-09 *Skyfall*), a nuclear-powered very-long-range nuclear-armed cruise missile; *Poseidon* (*Kanyon*), a nuclear-powered uninhabited underwater vehicle (UUV); *Sarmat* (RS-SS-X-30), a three-stage liquid-fuel ICBM; *Avangard* (RS-SS-19 *Stiletto* Mod 4), an HGV; *Kinzhal* (RS-AS-24 *Killjoy*), an air-launched ballistic missile (ALBM); and the *Tsirkon* ship-launched aero-ballistic missile. Even as a whole, these systems, some of which fall under the New START agreement, are unlikely to fundamentally shift the nature of the US–Russian strategic nuclear balance due to their likely low deployment numbers and with Russia's nuclear forces already fulfilling their primary deterrence purpose.

Nuclear Weapons

The core of Russia's deterrence system is its strategic nuclear forces.[15] The Russian leadership views nuclear weapons as central to ensuring Russia's role in a changing global, political and technological landscape.[16] These forces currently exist in a relationship of parity and mutual vulnerability with the US built during the Cold War.

Russia's strategic nuclear forces have been undergoing modernisation for over two decades. These efforts have extended to all three legs of the triad and related nuclear, production and early-warning infrastructure. Nuclear command and control received a boost with the 2014 inauguration of the National Defense Management Center.[17] As of the end of 2021, nearly 90% of equipment across the strategic nuclear forces was deemed modern by the government.[18] Over the next decade, the goal will be to maintain and increase this percentage, thus also guaranteeing the readiness of production lines.

To support the nuclear mission under the state defence order, Russia has several design bureaus and manufacturers as part of a dedicated defence-industrial base that focus on solid-fuel and liquid-fuel missiles and other components of nuclear systems. To date, much of Russia's challenge with missile development has had to do with manufacturing capability and capacity. Since the 2014 break in Russo-Ukrainian relations, Russia has sought to

ICBM MODERNISATION
The RS-24 *Yars* (RS-SS-27 Mod 2) is gradually replacing older Russian ICBMs in both mobile and silo configurations. CREDIT: Kirill Kudryavtsev/AFP/Getty Images

rebuild elements of indigenous design and construction capability to compensate for the loss of Yuzhmash and other Ukrainian companies that were previously part of the Soviet and Russian defence complex. However slowly, Russian nuclear modernisation has progressed and is now starting to bear fruit.

The New START agreement, in force until February 2026, limits the numbers of Russia's actively deployed strategic launchers and their related warheads. Hans Kristensen and Matt Korda estimate in the 2022 Nuclear Notebook that 1,588 warheads are deployed on Russian ICBMs, SLBMs and strategic bombers, while an additional 977 are held in reserve for these launchers. They further note that Russia likely reduced the number of warheads that it loads onto R-36/RS-20 (RS-SS-18 *Satan*) and RS-24 *Yars* (RS-SS-27 Mod 2) ICBMs, as well as the RSM-56 *Bulava* (RS-SS-N-32) SLBMs, for the purposes of New START compliance, thus building a warhead reserve that it could upload in a crisis (that is, rapidly add multiple warheads to missiles currently carrying only one).[19]

A key document outlining Russia's declaratory nuclear policy, 'The 2020 Foundations of State Policy of the Russian Federation in the Area of Nuclear Deterrence', envisions nuclear employment in the following circumstances:

1. Russia receives credible information that a ballistic-missile attack is incoming;
2. an adversary uses nuclear weapons/ weapons of mass destruction on Russian or allied territory;
3. an adversary inflicts damage to critical targets that could impact Russia's ability to retaliate;
4. conventional 'aggression' against Russia puts the 'very existence of the state … in jeopardy'.[20]

In addition to the above, it is also possible that the Russian military may recommend nuclear employment in war-fighting situations of critical-loss levels in the theatre of operations or in cases of significant losses of Russian territory.[21]

As with all nuclear states, Russia's declaratory policy is made credible through employment plans. While Russia's employment plans are classified, military journals provide some hints. In these writings, the Russian approach to nuclear weapons appears to prioritise the flexibility of options.[22] Strategic nuclear forces are intended first and foremost to deter a conflict (of any size) with the US and its allies. In a crisis, they could be used for signalling in escalation management. NSNWs, in turn, are intended for deterrence, escalation management and, if that fails, war fighting in a regional (Russia–US/ NATO) or large-scale (Russia–US/NATO and its allies) war. The key contingency of concern is a US/NATO massed-aerospace attack using conventionally armed weapons on Russian critical targets, where NSNWs have long been the refuge of Russian military planners. Military writings see a conflict potentially escalating all the way up to strategic nuclear retaliation, and some even envision the limited use of strategic nuclear forces before that takes place.[23]

Strategic Rocket Forces

Over 60% of Russia's warheads for strategic nuclear forces are on the ICBM leg of its nuclear triad, under the command of the Strategic Rocket Forces (RVSN).[24] According to RVSN commander Colonel-General Sergey Karakayev, the RVSN's ever-dominant role in the Russian 'nuclear triad is determined by the largest number of nuclear launchers, the number and yield of nuclear warheads and countermeasures'.[25] The RVSN's persistent focus has been on ensuring survivability because, according to Karakayev, the US 'will not only not give up attempts to nullify Russian strategic nuclear forces capabilities, but will also continue the search and implementation of new additional approaches to resolving these tasks'.[26] The RVSN's current goals include 'maintaining the required number of launchers in combat readiness, including during the rearmament period; the creation of new missile systems and the re-equipment of the RVSN, and the formation of a scientific and technical reserve in the field of creating new types of missile systems'.[27]

At present, the RVSN incorporates several different types of ICBM designs. The payloads of these different systems vary from those which carry a single nuclear warhead to others which carry multiple independently targeted re-entry vehicles (MIRVs). The RVSN's forces are split relatively evenly between silo-based and road-mobile missiles. This ratio between mobile and silo-based missiles is likely to persist for the near future.[28]

Two mainstays of the force, the solid-fuel RS-12M *Topol*-M (RS-SS-27 Mod 1) and the RS-24 *Yars* (RS-SS-27 Mod 2), were developed by the Moscow Institute of Thermal Technology (MITT) and built at the Votkinsk Machine Building Plant.[29] The single-warhead *Topol*-M ICBM is currently deployed in mobile and silo configurations with 78 launchers fielded.[30] With the capacity to carry three or possibly four MIRVs apiece, Russia's combined *Yars* mobile and silo ICBM arsenal of 180 launchers is able to carry between 540 and 720 warheads, totalling over half of Russia's total ICBM warheads at present.[31] The missile, which the RVSN began deploying in 2010, is undergoing upgrades to the *Yars*-S variant and potentially under a follow-up *Osina*-RV programme.[32] If the *Yars* replaces the RVSN's 78 mobile and silo-based *Topol*-M ICBMs, this would increase Russia's ability to upload a large number of warheads in a potential future environment that is no longer constrained by strategic arms control.[33] *Yars* was reportedly also the basis for *Sirena*-M command missiles that are 'intended to transfer command signals in case of an adversary first strike'.[34]

Reports suggest initiation of a *Yars* follow-on ICBM is under way with the *Kedr* programme. Work on the *Kedr*, reportedly funded under the current State Armament Programme (SAP), has reputedly begun for a mobile and silo-based ICBM that could replace the *Yars* around 2030.[35] Some Russian observers have charged that the *Kedr* may be a jobs programme for MITT.[36] MITT was where the *Barguzin* rail-mobile ICBM and the RS-26 *Rubezh* (reportedly an intermediate-range ballistic-missile modification of the *Yars* ICBM), both of which were excluded from the SAP in favour of the *Avangard* HGV, were designed.[37]

The relative newcomer to the RVSN is the liquid-fuel *Sarmat* ICBM, developed by the Makeyev Design Bureau and manufactured at the Krasnoyarsk Machine-Building Plant. The *Sarmat* is intended to replace the RVSN's roughly 46 R-36/RS-20 (RS-SS-18 *Satan*) ICBMs, which were the product of Ukraine's Yuzhmash plant. *Sarmat*, like the SS-18 it is slated to replace, is reportedly capable of being equipped with up to ten MIRVs.[38] *Sarmat* was first flight-tested in April 2022 following successful ejection tests in December 2017 and in March and May 2018. The RVSN intends to field the first *Sarmat* by the end of 2022, although this ambition is unlikely to be fulfilled given the missile's lack of testing and continuing production delays.[39] The ICBM will be deployed in silos that held the SS-18 as the missiles' dimensions are similar. Perennially focused on survivability, the missile's designers have claimed that 'the [upgraded] silo for *Sarmat* is a complex engineering structure that not only ensures the launch of the missile, but also guarantees its survival when hit by conventional high-precision weapons and nuclear ones. Due to its unique characteristics, the *Sarmat* will exit the silo under any conditions and is guaranteed to fulfil its task, no matter what.'[40] This likely refers to the missile being covered by a special coating that could protect it against radiation, electromagnetic pulses and particles in the event that the ICBM would travel through a mushroom cloud following a nuclear strike.[41] This technology was also applied to the RVSN's outgoing SS-18 Mod 5 ICBM.

SARMAT
Russia is developing a new silo-based ICBM, RS-28 *Sarmat* (RS-SS-X-29), to replace older equipment and act as the delivery vehicle for the *Avangard* HGV. CREDIT: Ministry of Defence of the Russian Federation

Some *Sarmat* ICBMs will carry the *Avangard* HGV instead of a MIRV payload. Development of the HGV by NPO Mashinostroyeniya began – or was restarted – in 2004, though the system's designer, Gerbert Efremov, has stated that experimentation with the concept – then known as *Albatross* – began as a response to the US Strategic Defense Initiative in 1985.[42] Like ballistic missiles, HGVs utilise rocket boosters for acceleration beyond the upper atmosphere. Unlike ballistic-missile payloads, however, which generally travel along arced exo-atmospheric trajectories, glide vehicles travel toward their targets on flight paths within the Earth's upper atmosphere following separation from the rocket booster. *Avangard* is reportedly capable of travelling at speeds of up to Mach 27 and of conducting cross-range manoeuvring.[43] Given *Sarmat*'s substantial throw-weight, it has been suggested that each ICBM will carry one or possibly two *Avangard* HGVs.[44] Due to delays with *Sarmat*'s development and deployment, the RVSN has modified six UR-100NUTTKh ICBMs as interim delivery vehicles for *Avangard* while *Sarmat*'s development is finalised. Deployment began in 2019 and the system was also inspected under New START.[45] Reports have suggested plans to have two missile regiments with six launchers apiece by 2027, under the current SAP.[46]

Another capability deployed at RVSN bases is the *Peresvet* directed-energy weapon. Its primary goal appears to be the protection of deployed Russian mobile transporter erector launchers (TELs).[47] Even though its full capabilities are unknown, *Peresvet* is apparently intended to use a laser to 'dazzle' – that is, to blind – an opponent's satellites and prevent targeting of the protected systems or critical infrastructure.[48] More broadly, Russian military thinkers have noted that directed-energy weapons are useful because of their selectiveness and their effectiveness in providing coverage to forces as well as command-and-control targets.[49]

Still another system displayed as part of Putin's 2018 'show and tell' is the *Burevestnik* nuclear-powered very-long-range nuclear-armed cruise missile. The idea behind the *Burevestnik* is the system's ability to potentially loiter for an extended period prior to striking targets due to its on-board nuclear-propulsion unit. The missile's nuclear-propulsion unit was responsible for a fatal accident in 2019 that killed seven scientists.[50] Little is known about the *Burevestnik* and which Russian branch/arm of the Russian forces it would deploy with, if and when it is finally completed. Russian reports have suggested the possibility of the system being deployed on a mobile launcher.[51]

Navy

The Russian Navy contributes to Russia's strategic nuclear forces and nuclear deterrence is a key part of the service's mission. Russia's SSBNs patrol irregularly, typically in bodies of water adjacent to their homeports in what is known as a 'bastion strategy', although it is likely that these boats also patrol further afield on occasion.[52] The modernisation of the undersea leg of Russia's strategic nuclear forces has been slow and characterised by delays to both new platforms and their principal weapons systems. The Russian industry has procured a new SSBN design, the *Borey* class (Project 955 (*Dolgorukiy*)) and *Borey*-A class (Project 955A), and their accompanying SLBM, the RSM-56 *Bulava* (RS-SS-N-32). The first Borey-class SSBN was commissioned in 2012.[53] Each boat can be equipped with up to 16 SLBMs. With the *Borey*-A SSBN now in series production, albeit slowly, at the Sevmash shipyard, the US Office for Naval Intelligence estimates that the Russian Navy will operate a fleet of ten of the new-design SSBNs by 2028, likely with five each deployed at Russia's Northern and Pacific Fleet bases respectively.[54] At present, the navy's strategic nuclear-deterrence mission is carried out by three *Borey* and two *Borey*-A boats, and six *Delfin*-class (Project 667BDRM (*Delta* IV)) SSBNs.[55] The older *Delfin*-class boats will likely be gradually retired as more

SSBN
The Russian Navy is slowly modernising its launch platforms and delivery vehicles. CREDIT: Alexander Zemlianichenko/AFP/Pool/Getty Images

Borey-A SSBNs are commissioned over the next decade.

One of the challenges with the *Borey* programme has been with the development of its SLBM, the *Bulava*, which can carry six MIRVs. Designed by MITT and manufactured at the Votkinsk Machine Building Plant, the missile took two decades from conception to entry into service, with a series of high-profile test failures.[56] The *Delta* IV SSBNs, in turn, carry the older R-29RMU2 *Sineva* (RS-SS-N-23 *Skiff*) and R-29RMU2.1 *Layner* (RS-SS-N-23 *Skiff*) designed by the Makeyev Design Bureau and manufactured by the Krasnoyarsk Machine-Building Plant. Both the *Sineva* and *Lainer* can be equipped with up to four MIRVs. If all missiles are fully uploaded, Russia's five *Borey*-class boats can deploy with 480 warheads while the navy's six *Delfin*-class SSBNs can deploy with 320 warheads.[57]

One novel capability for the Russian Navy will be the much-heralded *Poseidon*/*Status*-6 (*Kanyon*) large UUV. Revealed in Russian reports in 2015 and akin to a giant torpedo, the *Poseidon* is both nuclear powered and potentially nuclear armed.[58] With very long range, it may be intended for the destruction of critical coastal infrastructure.[59] However, its operational concept and precise status remain uncertain. The *Belgorod* (Project 09852) – a specially modified SSBN – is apparently able to accommodate six of the UUVs and was entered into service in July 2022.[60] A second vessel, the *Khabarovsk* (Project 09851), is reportedly in the advanced stages of construction at Sevmash and appears to be a somewhat modified design.[61] There have also been reports of improvements of infrastructure at several bases in the Northern Fleet to accommodate its introduction.[62]

Another novel capability the Russian Navy will soon have access to is the *Tsirkon*. Although Russian officials have said the missile is a hypersonic cruise missile, some analysis suggests that it is likelier it is a modified aero-ballistic missile because of the absence of certain features that are necessary for high-speed air-breathing designs.[63] Developed by NPO Mashinostroyeniya, *Tsirkon* is intended for deployment on numerous ships across the surface fleet and submarines, such as the Project 22350 (*Gorshkov*) frigate *Admiral Gorshkov* and the Project 885 (*Yasen*) nuclear-powered cruise-missile submarine (SSGN), and is currently in the final stages of state trials.[64]

The addition of new *Yasen*- (Project 885) and *Yasen*-M-class (Project 08851) SSGNs and the procurement of new cruise-missile systems, including with land-attack and nuclear capabilities, have added a new dimension to the Russian Navy's conventional and nuclear-deterrence missions, given the SSGN's ability to conduct long-range precision strikes with NSNWs and non-nuclear systems and also participate in escalation management.[65] Estimates for the number of NSNW warheads the Russian Navy possesses vary, but some analysts suggest there are just under 1,000 warheads that potentially could be intended for capabilities that could be classified as on submarines, surface ships and other assets.[66]

Russia is continuing construction of new *Yasen*-M-class SSGNs. The second vessel, *Krasnoyarsk*, is currently undergoing sea trials, and six other boats are under construction at Sevmash.[67] The *Yasen*-M is able to launch the 3M14 *Kalibr* (RS-SS-N-30A *Sagaris*) land-attack cruise missile (LACM) and will likely eventually be equipped with the *Tsirkon*. The *Yasen*-M is perhaps Russia's most formidable undersea capability and is intended to conduct operations against surface ships and submarines, hit targets on land with both conventional precision and potentially nuclear cruise missiles – including hypersonic systems – and guard the SSBN bastion.[68]

Much of the West's attention has been on the 'Kalibrisation' of the Russian Navy. The *Kalibr* is a versatile LACM that was successfully demonstrated during Russian operations in Syria. It is currently undergoing upgrades, potentially including a range extension, at NPO Novator.[69] The ship- and submarine-launched versions of

SSGN
The *Yasen*-M class adds a new dimension to the Russian Navy's conventional and nuclear-deterrence missions. CREDIT: Vladimir Rodionov/Stringer/AFP/Getty Images

HEAVY BOMBERS
Russia's Tupolev Tu-160 strategic bombers have been modernised to deliver nuclear and conventional Kh-101/102 (RS-AS-23A/B *Kodiak*) ALCMs.
CREDIT: Federico Parra/AFP/Getty Images

the missile have also been used on targets in Ukraine in the ongoing Russian invasion.[70] Two other conventionally powered submarine classes, the *Varshavyanka* Project 06363 (Improved *Kilo*) 636 and *Lada* (Project 677 (*Petersburg*)), can also be armed with *Kalibr* LACMs. Among the navy's modern major surface units, the Project 22350 *Gorshkov* class, the first two of which are in service, can be armed with *Kalibr* missiles, as can other modern surface-combatant classes, and the lead Project 22350 vessels have also reportedly conducted trials with *Tsirkon*.[71]

Aerospace Forces

Russia's Aerospace Forces (VKS) also have nuclear-deterrence tasks. In addition to the mission of long-range aviation (LRA) bombers, these include intelligence, surveillance and reconnaissance (ISR), detection and early warning, participation in countering an adversarial attack, and point defence of strategic nuclear forces and other critical targets.[72] Military thinkers also argue for the importance of achieving and maintaining dominance in the aerospace domain during a conflict where adversaries will use emerging technologies such as hypersonic boost-glide and cruise missiles and uninhabited systems.[73] This, some posit, is the reason for Russia's extensive upgrades to airframes and the procurement of new cruise missiles and capabilities.[74] Analysts attribute roughly 580 warheads to LRA and about 500 for NSNWs on fighter-bombers such as the Tu-22M3 and the MiG-31K.[75]

The LRA's two strategic bombers, the Tu-160 and the Tu-95, mainstays of the Russian triad since the Cold War, have been extensively upgraded and feature the dual-capable *Raduga* Kh-101/102 (RS-AS-23A/B *Kodiak*) long-range ALCM system, which is a replacement for the Raduga Kh-55 (RS-AS-15A/B *Kent)* ALCM. The Kh-101 missiles, which Russia first used during its operations in Syria, have experienced significant failure rates during Russia's invasion of Ukraine, according to US defence officials.[76] The reasons for these failures are unclear, and at least some of these problems seem to have stemmed from launch aircraft.

The future of Russia's new-generation strategic bomber, the PAK DA, is uncertain. Russia recently restarted the manufacture of the Tu-160 *Blackjack* fleet, with plans to procure 50 Tu-160M, with ten already under contract.[77] This aircraft had a maiden flight in January 2022.[78] Authorities have articulated plans to have parallel manufacturing of the Tu-160 and the new bomber.[79] The design to meet PAK DA was supposed to enter serial production sometime before 2030.[80] The capacity of Russian industry to manufacture two bomber designs in parallel, however, is questionable.

A novel capability in the VKS is the dual-capable *Kinzhal* (RS-AS-24 *Killjoy*) ALBM that is deployed on the MiG-31K (*Foxhound* D). The system is intended to target regional critical infrastructure. According to US officials, *Kinzhal* has been used several times in Ukraine, including for a strike on a Ukrainian arms depot.[81] Russian military thinkers also note the possibility of its use for escalation management in the non-nuclear phase of a conflict.[82]

The Russian military is dedicating increased attention to the space domain.[83] Here, the VKS is developing air/missile defence systems such as the S-500 and the A-235 *Nudol*, which likely have counter-space capabilities.[84] Russia has developed extensive counter-space capabilities and conducted destructive anti-satellite weapons testing.[85] Analysts have also assessed Russia has used non-destructive counter-space capabilities in the ongoing Russia–Ukraine war.[86]

Ground Forces

While the Russian Ground Forces possess strategic systems, they have several precision-strike capabilities intended for use at the operational-tactical level. These systems have been a matter of concern for US allies because of their ability to be used for both conventional and nuclear missions, as well as their mobility. They have also been at the centre of US allegations of Russia's non-compliance with the Intermediate-Range Nuclear Forces (INF) Treaty. Around 100 nuclear warheads are attributed to these ballistic- and cruise-missile capabilities.[87]

The *Iskander*-M (RS-SS-26 *Stone*) solid-fuel SRBM, developed by KBM and produced at Votkinsk, was designed as a replacement for the *Tochka*-U (RS-SS-21 *Scarab*) SRBM, which entered service in 1989. *Iskander* is perhaps closest in design and capabilities to the *Oka* (RS-SS-23 *Spider*) system that was destroyed as part of the INF Treaty deal, much to the chagrin of the Russian military and defence industry. The SRBM is able to strike targets up to 500 kilometres away with a 480-kilogram payload. The *Iskander* system is also able to launch cruise missiles, including the 9M728 (RS-SSC-7 *Southpaw*) and 9M729 (RS-SSC-8 *Screwdriver*) cruise missiles.[88] Russia has used the *Iskander* system in both roles during its invasion of Ukraine. And, recently, Putin indicated the possibility of transferring the *Iskander*-M to Belarus as part of a defence pact between the two states.[89]

The 9M729 is a dual-capable mobile system and is almost certainly a ground-launched variant of the Novator *Kalibr*. The development and testing of the system, which far exceeds the 500-km threshold of the INF Treaty, was at the centre of the US exit from the agreement. Several battalions have reportedly been operationally deployed.[90]

Future Trends in Modernisation

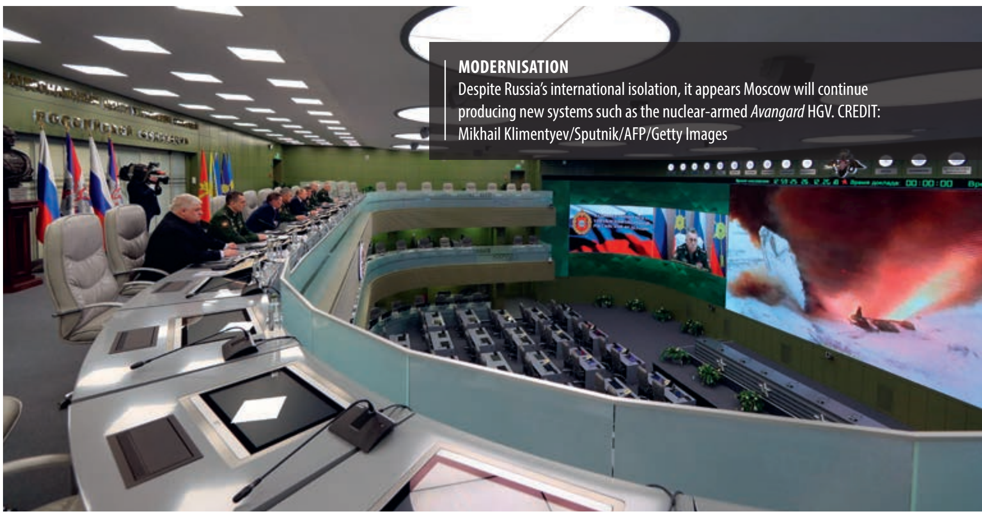
The ongoing Russia–Ukraine war is stress-testing the Russian military modernisation that was initiated after the military's poor performance in the 2008 Russo-Georgian War. It is also potentially challenging the goals of its future modernisation. It is certain that the Russian armed forces will go through another extensive period of learning. In turn, the West's political and economic responses to Russia's invasion will have impacts on Russia's economy and its military. Russia may be unable to source certain components required for weapons because of sanctions. But these impacts will take time to crystallise and the implications for the Russian military or defence industry may not be as simple as some headlines suggest.

Prior to the Russia–Ukraine war, Russia's defence spending was expected to stay relatively stable, with procurement focused on raising the quality (as opposed to quantity) of military capabilities.[91] The military steadily procured conventional and nuclear systems through the SAP. The SAP-2027 was focused, amongst other priorities, on continuing to modernise all three legs of Russia's nuclear triad and aerospace defence capabilities, as well as procuring 'novel' systems.[92] Russia also continued to modernise its defence-industrial base, given its inability to access familiar missile-production sites in Ukraine given the poor relations between Kyiv and Moscow following Russia's 2014 annexation of Crimea. In response to this impediment, Russian investment has included upgrades to the Krasnoyarsk Machine-Building Plant, amongst others, as well as to component manufacturing.[93]

SRBM
The 9K720 *Iskander*-M (RS-SS-26 *Stone*) can be equipped with either conventional or nuclear warheads and has been used extensively in Russia's invasion of Ukraine. CREDIT: Contributor/Getty Images

The intended direction of Russian military modernisation, at least before the war against Ukraine, was best glimpsed through the writings of military thinkers close to the Russian General Staff. These suggested the continued importance of information warfare (broadly understood) and posited that Russia, like countries around the world, needed to prioritise the development of uninhabited and robotic systems (ground, air and sea); operations in the space domain; improvements in guidance, self-targeting and increases in ranges of naval systems; as well as the integration of artificial intelligence into military systems.[94]

The Russia–Ukraine war does not yet appear to have shifted the focus



MODERNISATION
Despite Russia's international isolation, it appears Moscow will continue producing new systems such as the nuclear-armed *Avangard* HGV. CREDIT: Mikhail Klimentyev/Sputnik/AFP/Getty Images

of the SAP-2033, at least rhetorically.[95] This future SAP still intends to address the requirements of the 'intellectualisation of weapons'.[96] As Putin described it prior to the war, SAP-2033 will focus on developing 'modern and future models of high-precision weapons and means of aerospace defence, active employment of artificial intelligence in developing military goods' as well as 'unmanned reconnaissance and strike aerial vehicles, laser and hypersonic systems, weapons based on new physical principles, as well as robotic complexes, which could perform diverse roles on the combat field'.[97]

These proposed developments in military technology do not exist in a political vacuum. Russian military thinkers look out at the international environment to examine what the current trendlines of conflict suggest for the future. Even despite the initiation of the Russia–Ukraine war, they have continued to view the likelihood of large-scale war against Russia as relatively low. However, the writings paint a dizzying array of future challenges: 'conflicts of the future most likely will be associated with the fight against terrorism, the conduct of "hybrid" actions in the "grey zone", asymmetric actions, local, regional and other as yet insufficiently studied wars and armed conflicts with a real possibility of limited use of nuclear weapons'.[98] All of these require a flexible set of capabilities coupled with a responsive defence industry.

Russian industry has been faced with the need to replenish weapons stocks to enable the continuation of the Russian invasion of Ukraine. At the same time, Western sanctions have sought to limit Russia's ability to manufacture weapons with high-tech components. Headlines about the potential impact have suggested a dire state at individual Russian defence plants.[99] However, some observers have noted that it does not yet appear that the Russian defence industry is experiencing a significant shortage of components as of this writing.[100] US officials have argued that Russia has used up significant amounts of some of its missile systems.[101] Russian officials have stated, however, that on the whole, procurement of these systems has continued relatively steadily.[102] There have been reports about increases in shifts at defence plants, but these remain largely unconfirmed, as do the numbers of procurement increases for specific missile systems.[103] On the whole, Russian defence spending since the war began has risen and there is a possibility that this heightened spending will be sustained for some time, even with the stress on the Russian economy.[104]

Implications of the War in Ukraine

Western observers have raised concerns about the prospect of Russian nuclear use as part of war termination in Ukraine, particularly if the conflict looks as if it will end poorly for Moscow.[105] As of this writing, this scenario seems less likely than Russian use of nuclear weapons to deter escalation of the Russia–Ukraine conflict from a local to a regional war. So far, Russian nuclear rhetoric and signalling, such as the 27 February 'special nuclear regime' that slightly increased manning levels as well as nuclear exercises, appear to be limited to forestalling the prospect of a Western military intervention.

However, the Russian military has already tolerated a substantial influx of significant Western weapons to Ukraine. As such, it contends that the conflict is in essence a proxy war aimed at assuring US strategic dominance and promotes propaganda about pre-war US and Ukrainian bioweapons research efforts aimed against Russia.[106] These narratives raise questions about Russian red lines in Ukraine and what Moscow would do in terms of their enforcement. As the war continues, some argue that the attractiveness of nuclear coercion to achieve political ends could increase for Russia. Potential avenues could take the form of more significant increases in alert levels of strategic nuclear forces, the conduct of a demo or a test over water, or potential use of NSNWs.[107] However, Russia still retains potent non-nuclear options, including but not limited to counter-space and cyber or precision strikes against critical-infrastructure targets in Europe or the US, for coercion, escalation management and war fighting.

On a theoretical level, it is possible that the Russian political and military leadership's views on nuclear weapons may be at an important inflection point due to the poor performance of the Russian armed forces in Ukraine and shifts in Russia's opponents' perceptions about the Russian military's ability and will to fight more broadly. It remains possible, indeed likely, that Russia may be forced to increase its reliance on NSNWs as the result of its failures in the Russia–Ukraine war.

Even if the Russia–Ukraine war does not result in Russian nuclear employment, Moscow's global reputation has been tarnished in ways that the Russian leadership did not anticipate. Russia is now involved in a protracted war – again, a situation it did not anticipate – with its conventional might in question. All of these factors could erode Russia's standing as a great power, with significant implications for its role in the global economy. As a result, Russia's nuclear weapons could play an even greater geopolitical role in the decades to come – as they did in the 1990s.

Differences in Strategic Stability

Another consequence of the decision to invade Ukraine was the halt in the US–Russian Strategic Stability Dialogue (SSD). The SSD heralded the potential start of negotiations between the US and Russia on future arms control on nuclear weapons, such as a New START follow-on agreement and potential agreements on emerging and disruptive technologies. The process, however, also showed that Moscow and Washington have different priorities regarding strategic stability and future arms control.

In a continuation from the previous US administration, the primary focus of President Joe Biden's government was on Russian nuclear weapons, which included interest in an agreement covering all warheads, deployed and non-deployed.[108] An issue important to NATO allies and to the US Congress, there was an expectation that the next treaty with Russia would at the very least begin to address NSNWs. The administration was also interested in limits on Russia's novel nuclear systems.

Russian officials, in turn, sought to focus on the relationship between nuclear and non-nuclear capabilities because of a set of offensive and defensive conventional systems that affect Russian nuclear planning. They have described this 'entire spectrum of both nuclear and non-nuclear offensive and defensive arms that are capable of resolving strategic tasks' as a 'strategic equation'.[109] This broader Russian list included missile defence, nuclear and conventional offensive weapons that can achieve strategic effects, and space issues.[110] The US allowed missile defence's inclusion on the agenda only if Russian developments on missile defence were also included in the SSD talks.

Russian Deputy Foreign Minister Sergei Ryabkov explained Russian priorities before the talks:

> We need to look carefully at the attack systems that could be used in a first counterforce strike at the territory of the other side with a view to neutralising or weakening its deterrence potential. Relevant technology is being developed quickly, and today strategic objectives can be partly achieved with conventional precision weapons. That said, we consider it justified to maintain a focus on delivery vehicles and their carriers, including missile launchers. As for warheads, we suggest, as before, concentrating on the deployed warheads that pose the biggest operational threat.[111]

Some of these have been consistent talking points for the Russian side for a decade or more, but the urgency of tackling them had arguably grown because of technological evolution coupled with reduced nuclear numbers. There was also continued interest on the Russian side in terms of engagement on INF systems, which was also reciprocated by the US.[112]

Russian officials did not appear particularly interested in explicit negotiations on its NSNWs or its novel nuclear systems as a focus for the next arms-control agreement.[113] As discussed earlier in this chapter, the Russian military requires NSNWs for a regional war with the conventionally superior US/NATO armed forces while its boutique capabilities are important counters to emerging Western technologies and possible US technological breakouts. Thus, the US fixation on precisely these capabilities may have been viewed as an explicit effort to publicly pressure Russia into disadvantageous concessions.

The SSD participants met in July and September 2021 to discuss pressing issues of concern and agreed on several working groups, one that included issues on the Russian 'strategic equation' list, to discuss specific next steps.[114] While the SSD process operated in theory until Russia invaded Ukraine in February 2022, it likely halted sometime in late 2021 when Russian preparations for an invasion – and Western deterrence activities to counter this – began in earnest.[115]

Challenges for Future Arms Control

The prospects for future nuclear-arms control are challenging. Without the SSD process, important topics that were on the agenda of that forum, such as the impact of emerging technologies on strategic stability, will remain unaddressed. And, because the SSD intended – amongst other goals – to serve as a stepping stone to a follow-on agreement to the New START agreement, it is now possible that the treaty will expire in 2026 without a replacement.

US and Russian officials have stated their openness to arms-control negotiations.[116] In practical terms, however, the Russia–Ukraine war has imposed considerable political and moral pressure on the Biden administration domestically and among NATO allies to refrain from negotiations or from giving the impression of returning to 'business as usual'. For any arms-control discussions to be successful, the US will possibly have to overcome

STRATEGIC STABILITY
US President Joe Biden and Russian President Vladimir Putin meet at the 2021 Geneva Summit, 16 June 2021. CREDIT: Peter Klaunzer/Pool/Keystone/Getty Images

UKRAINE
Russia's continued war of aggression against Ukraine may limit US options for future bilateral arms control. CREDIT: Aleksandr Gusev/SOPA Images/LightRocket/Getty Images

the perception of its European allies that pursuing bilateral agreements is of greater US national interest than dealing with Russian aggression in Europe.

Once New START expires in 2026, the US–Russian strategic relationship could further unravel. According to the Russian side, the monitoring and verification provisions of the agreement currently 'allow for the accurate forecasting of [both sides' strategic nuclear forces'] military capabilities for a given period'. [117] In turn, the collapse of bilateral arms control could open up the possibility of an 'uncontrolled U.S. build-up of strategic nuclear forces'.[118] Russian analysts have also argued that significant US deployments of hypersonic glide vehicles or hypersonic cruise missiles could have implications for the survivability of Russia's silo-based ICBMs.[119] For the US, the end of New START would similarly imply the need to plan for a significant expansion of the number of Russian launchers and deployed strategic and non-strategic warheads. In an environment of an evolving nuclear threat from China and North Korea (and possibly Iran), this prospect might not seem particularly attractive. The easiest option for both sides might be to maintain New START limits beyond 2026. However, such limits probably would not be easily achieved without a legally binding agreement that has monitoring and verification provisions. That said, the political climate in the US meant that ratification of a legally binding agreement was a non-starter in the US Senate even before the Russia–Ukraine war.

A redefined security situation in Europe will likely make the US goal of achieving limits on Russian NSNWs (or transparency of all warheads) very difficult. It will also leave the US and NATO contending with Russian conventional deterrence capabilities. Russia, in turn, will have to contend with a changed threat from the US coupled with a strengthened and geographically further expanded NATO on its doorstep, and its responses, such as an increased reliance on NSNWs, may have implications for US and European security. Some Russians have noted the possibility of a Russian nuclear-posture/planning shift toward pre-emption if the US/NATO deployed conventionally armed intermediate-range systems in the region.[120] Others have posited the possibility of 'novel' nuclear systems taking on a more significant dimension in Russian nuclear forces.[121]

There is some evidence of evolution in the Russian position on missile defence. Ryabkov stated before the SSD that 'Russia does not intend to give up the principle of an inseparable link between strategic offensive and strategic defensive arms'.[122] Russian military thinkers still worry that 'left of launch' concepts in US missile defence 'remove the boundary between offensive (strike) and defensive weapons' and note concerns about the evolution of US missile-defence infrastructure in space.[123] However, Russian capabilities to counter missile defence and Russia's own growing defensive capabilities have evolved since the two sides previously negotiated on arms control. In turn, articles by Russian military thinkers suggest a shift toward arguments that a situation where US global missile defence creates instabilities in a US–Russian nuclear-crisis situation might not be beneficial to the US.[124] They suggest the negotiation of keep-out zones for certain US sea-based missile-defence capabilities as an example.[125] Such talks would have to bring in US allies and may also have to run counter to the current US domestic political consensus on the unwillingness to negotiate missile-defence restrictions with adversaries.

Other potential avenues for risk-reduction progress involve multilateral arms-control configurations. These could bring in the US and Russia in a negotiating forum with China, or even potentially in a P5-like format with France and the United Kingdom also included. They could also involve risk-reduction negotiations between NATO and Russia (and the P5) in terms of non-nuclear strategic (conventional) and nuclear issues. Such formats were under consideration before the Russia–Ukraine war, and only time will tell if the events of the war have rendered these ideas beyond resuscitation. Of course, any use of nuclear weapons in the ongoing conflict is bound to completely change the terms of the debate. In short, today is not the right day for risk reduction, but tomorrow might be.

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CHAPTER FIVE

United States

The adage 'the more things change, the more they stay the same' could readily apply to US nuclear posture and policy. Historically, while US nuclear-weapons spending has increased, little else has changed: modernisation programmes have largely maintained a US nuclear posture primarily aimed at deterring Russia, with China, North Korea and Iran considered as secondary concerns. That is, perhaps, until recently. Qualitative improvements and arms racing of missile technologies, China's apparent expansion of its nuclear arsenal and Russia's nuclear sabre-rattling over Ukraine may result in a shift of this historically anchored position. Washington's posture, fundamentally stable since the Cold War, may or may not persist under these changing conditions. There is, furthermore, debate in the United States as to whether the country's nuclear arsenal remains fit for purpose, with some now arguing it is inadequate whilst others maintain that it can still be further reduced.

US Nuclear-force Structure

The US maintains a 'triad' of nuclear-delivery vehicles, comprising ground-, air- and sea-launched missile systems. The three 'legs' of the triad are designed to work together to ensure a second-strike capability.

Land

The United States' land-based missile inventory consists of 400 Boeing LGM-30G *Minuteman* III intercontinental ballistic missiles (ICBMs) that are operated by the US Air Force (USAF). The ICBMs are deployed in silos at the 90th Missile Wing at Francis E. Warren Air Force Base in Wyoming, the 341st Missile Wing at Malmstrom Air Force Base in Montana and the 91st Missile Wing at Minot Air Force Base in North Dakota. Although there are 450 silos across these three sites, only 400 have missiles deployed in them. The *Minuteman* III ICBM has a maximum range of over 12,000 kilometres.[1] The United States' ICBMs are maintained on 'high alert' status and serve as a first-strike deterrent force: if an adversary were to launch a strike against the US, these ICBMs could be launched whilst under attack:

Key takeaways

UPDATED TRIAD

The United States' nuclear-modernisation efforts largely aim to upgrade the United States' ageing triad with new technology with the intent of maintaining reliability, though some systems will see qualitative improvements consistent with broader US Department of Defense efforts to offset adversary advancements and maintain a competitive edge.

POST-INF SYSTEMS

The collapse of the Intermediate-Range Nuclear Forces Treaty (INF Treaty) in 2019 has allowed the US to develop ground-launched systems with ranges beyond 500 kilometres. The Trump and Biden administrations' post-INF strategies are intended to counter China's and, to a lesser extent, Russia's advantages in this area.

NEW DETERRENCE FRAMEWORKS

Maximising the utility of some post-INF systems will be partly dependent on agreements with US allies and partners. NATO's decision at the 2022 Madrid Summit to strengthen its deterrence and defence capabilities might mean that the deployment of these types of land-based systems in Europe will be more politically feasible than prior to Russia's invasion of Ukraine.

HIGH-SPEED PURSUITS

Washington is unilaterally and cooperatively pursuing very-high-speed cruise-missile and glide-vehicle technologies. While some analysts have suggested that the US is behind China and Russia in this field, the US has multiple programmes under way for conventional systems that will be fielded from 2023 onwards.

NEAR-PEER NUCLEAR RIVALS

China and Russia continue to evolve their nuclear-force structures and postures and the threat from China's growing nuclear stockpile is likely to continue to catalyse change within the US nuclear apparatus.

- **W87/Mk21 (300 kilotons):** the W87 is an American thermonuclear warhead formerly deployed on the LGM-118A *Peacekeeper* ('MX') ICBM. Fifty *Peacekeeper* missiles were built, each carrying up to ten W87 warheads in MIRVs. Beginning in 2007, 250 of the W87 warheads from retired *Peacekeeper* missiles were retrofitted onto older *Minuteman* III missiles, with only one warhead paired with each missile.
- **W78/Mk12A (335 kilotons):** the W78 is an American thermonuclear warhead that has an estimated yield of roughly 335 kilotons of TNT, deployed on the LGM-30G *Minuteman* III ICBM and housed in the Mark 12A MIRVs. The *Minuteman* III initially carried the older W62 warhead, which has a yield of 170 kilotons of TNT.

Sea

The US Navy (USN) operates 14 *Ohio*-class nuclear-powered ballistic-missile submarines (SSBNs). Of these boats, eight operate in the Pacific Ocean, based out of Bangor Base, Washington, while six operate in the Atlantic Ocean, based out of Kings Bay Base, Georgia.[2] SSBNs are generally held to be the most survivable leg of the triad, providing a secure retaliatory capacity in the event of a first strike. Each *Ohio*-class SSBN is equipped with up to 20 Lockheed Martin UGM-133A *Trident* II D-5LE submarine-launched ballistic missiles (SLBMs). *Ohio*-class SSBNs were originally designed to carry up to 24 SLBMs, each of which can be armed with eight multiple independently targetable re-entry vehicles (MIRVs). However, under limitations from the New Strategic Arms Reduction Treaty (New START), four of each SSBN's missile tubes have been permanently deactivated. The *Trident* II D-5LE has an estimated range of around 12,000 km:

- **Enhanced W76-1 (90 kilotons):** the W76-1 is a refurbished American thermonuclear warhead that is now used with the UGM-133 *Trident* II. Its predecessor, the W76-0, was introduced into the US Navy's nuclear stockpile in 1978 and was replaced by the W76-1 between 2008 and 2018. The W76-1 Life Extension Program (LEP) extended the original warhead service life from 20 to 60 years. The W76-1 meets all missions and capabilities of the original W76-0 warhead without providing new military capabilities. Though each *Trident* II can carry 12 100-kt W76 warheads (with Mark 4 MIRVs), under the New START *Trident* II missiles are limited to eight warheads each.
- **W76-2 (8 kilotons):** the W76-2 warheads are low-yield nuclear warheads that were converted from Mod 1 (W76-1) warheads in accordance with the 2018 Nuclear Posture Review (NPR). Each warhead has a yield of 90–450 kilotons. Not without controversy, the first W76-2 warheads were deployed in late 2019.
- **W88 (455 kilotons):** the W88 is a high-yield American thermonuclear warhead. The latest version is called the W88 ALT 370, having entered into production in 2021, after 11 years of development. A *Trident* II SLBM can be armed with up to eight W88 warheads (using a Mark 5 MIRV).

Air

The USAF fields two bomber types in the nuclear role, the Boeing B-52H *Stratofortress* and the Northrop B-2A *Spirit*. US bombers can be used to launch several types of nuclear weapons, including the AGM-86B air-launched cruise missile (ALCM), as well as nuclear gravity bombs such as the B-61. While the SSBNs are considered to be the most survivable, the bomber force is seen as the most flexible element of the triad, as its deployment offers a means of signalling. For example, the US has used its bombers for signalling in response to North Korea's escalatory actions, with B-52H and B-2A bombers flown to South Korea in a show of strength and support for South Korea[3]:

- B-2A bombers carry B61-7, B61-11 and B83-1 gravity bombs
- B61-7 (variable yield from 10–340 kt)
- B61-11 (400-kt yield)
- B83-1 (variable yield ranging from very low to 1.2 megatons)
- B-52 H bombers carry AGM-86B ALCMs
- AGM-86B: carries a 200-kt W80-1 nuclear warhead with a range of over 2,400 km.

US Nuclear-force Structure: Nuclear-weapons Stockpile

As of September 2020, the US has an arsenal of approximately 5,750 nuclear warheads, down from a peak of 31,255 in 1967.[4] Of these, 3,750 are in its active stockpile, while roughly 2,000 are retired and awaiting dismantlement. Within the active-warhead stockpile, the US has 1,515 warheads deployed on ICBMs, SLBMs and heavy bombers, according to the most recent New START data exchange. Under the limitations of the New START, the number of deployed strategic nuclear warheads is capped at 1,550 and the number of strategic launchers (ICBMs, SLBMs and bombers) at 800, of which only 700 may be deployed.

Land

The USAF equips each of its *Minuteman* III ICBMs with a single nuclear warhead. These are either the 300-kt W87/Mk21 or the 335-kt W78/Mk12A.

- **W87/Mk21 (300 kilotons):** the W87 is an American thermonuclear warhead formerly deployed on the LGM-118A *Peacekeeper* ('MX') ICBM. Fifty *Peacekeeper* missiles were built, each carrying up to ten W87 warheads in MIRVs. Beginning in 2007, 250 of the W87 warheads from retired *Peacekeeper* missiles were retrofitted onto older *Minuteman* III missiles, with only one warhead paired with each missile.
- **W78/Mk12A (335 kilotons):** the W78 is an American thermonuclear warhead that has an estimated yield of roughly 335 kilotons of TNT, deployed on the LGM-30G *Minuteman* III ICBM and

housed in the Mark 12A MIRVs. The *Minuteman* III initially carried the older W62 warhead, which has a yield of 170 kilotons of TNT.

Sea

The US has 944 sea-launched nuclear warheads that reside on 14 SSBNs, each of which is equipped with 20 SLBMs.[5] The warheads that are fitted to the *Trident* II D-5LE are either:

- **Enhanced W76-1 (90 kilotons):** the W76-1 is a refurbished American thermonuclear warhead that is now used with the UGM-133 *Trident* II. Its predecessor, the W76-0, was introduced into the US Navy's nuclear stockpile in 1978 and was replaced by the W76-1 between 2008 and 2018. The W76-1 Life Extension Program (LEP) extended the original warhead service life from 20 to 60 years. The W76-1 meets all missions and capabilities of the original W76-0 warhead without providing new military capabilities. Though each *Trident* II can carry 12 100-kt W76 warheads (with Mark 4 MIRVs), under the New START *Trident* II missiles are limited to eight warheads each.
- **W76-2 (8 kilotons):** the W76-2 warheads are low-yield nuclear warheads that were converted from Mod 1 (W76-1) warheads in accordance with the 2018 Nuclear Posture Review (NPR). Each warhead has a yield of 90–450 kilotons. Not without controversy, the first W76-2 warheads were deployed in late 2019.
- **W88 (455 kilotons):** the W88 is a high-yield American thermonuclear warhead. The latest version is called the W88 ALT 370, having entered into production in 2021, after 11 years of development. A *Trident* II SLBM can be armed with up to eight W88 warheads (using a Mark 5 MIRV).

Air

There are 300 nuclear warheads that are designed to be air-launched (from bombers) at two USAF bases: 200 at Minot AF Base in North Dakota and 100 at Whiteman AF Base in Missouri. The USAF operates an estimated total of 60 strategic bombers, although not all are believed to be operational at the same time. The force is roughly divided as 20 B-2A nuclear-capable bombers and 40 B-52 H nuclear-capable bombers.

Additionally, the US has deployed roughly 100 non-strategic B61 nuclear gravity bombs to bases in Belgium, Germany, Italy, the Netherlands and Turkey. Other nuclear gravity bombs that are non-deployed, held in reserve or retired are believed to be stored at various locations including in Colorado, Georgia, Louisiana, Nevada, New Mexico, Texas and Washington.[6]

Figure 5.1: The United States' nuclear triad

Name	Type	Fuel type	Range (km)	Warhead type and number	Basing option	Number of stages	Number of launchers (estimated)	Initial operational capability
LGM-30G *Minuteman III*	ICBM	Solid	12,000+	Nuclear x 1	Silo	3	400	1970
UGM-133A *Trident* D5/D5-LE	SLBM	Solid	12,000+	Nuclear x 8	*Ohio*-class SSBN	3	280	1990
AGM-86B	ALCM	Turbofan	2,400+	Nuclear x 1	B-52H *Stratofortress*	N/A	500	1982
B61-7/11	Gravity bomb	N/A	N/A	Nuclear x 1	B-2A *Spirit*	N/A	300	1985 (B61-7) 1997 (B61-11)
B83-1	Gravity bomb	N/A	N/A	Nuclear x 1	B-2A *Spirit*	N/A		1983

Sources: IISS; *The Military Balance 2022*; *Bulletin of the Atomic Scientists*

- B-2A bombers carry B61-7, B61-11 and B83-1 gravity bombs
  - B61-7 (variable yield from 10–340 kt)
  - B61-11 (400-kt yield)
  - oB83-1 (variable yield ranging from very low to 1.2 megatons)
- B-52 H bombers carry AGM-86B air-launched cruise missiles
  - AGM-86B: carries a 200-kt W80-1 nuclear warhead with a range of 2,500 km.

US Nuclear Posture: The Triad Debate and the Nuclear Posture Review

The United States Department of Defense (DoD) has produced four NPRs, with the first completed on 22 September 1994.[7] This was the first comprehensive review of nuclear posture since 1979 and described the administration's approach to a reduced role for nuclear weapons compared to that during the Cold War,

LANCE
Nuclear-armed missiles such as the MGM-52 *Lance* are removed from the US Army's inventory as part of the 1991–92 Presidential Nuclear Initiatives (PNIs). CREDIT: Leif Skoogfors/Corbis Historical/Getty Images

covering the topics of policy, doctrine, force structure, command and control, operations, supporting infrastructure, safety, security and arms control. The subsequent three NPRs were mandated by law. In 2000, the National Defense Authorization Act (NDAA) required that a new NPR include six elements: 1) the role of nuclear weapons; 2) how to maintain safety, reliability and credibility; 3) the relationship between nuclear deterrence, targeting and arms control; 4) the numbers and types of nuclear-delivery systems; 5) the number of 'active' and 'inactive' warheads; and 6) the required nuclear-weapons complex.[8] In 2008, the NDAA required a revised NPR, but added a seventh requirement: to describe the impact of missile defence and conventional capabilities on the size and composition of the nuclear deterrent.[9] Ten years later, in 2018, the NDAA required that the revised NPR address the deterrent effect and operation of US nuclear forces in current and future security environments.[10] This requirement was dropped in 2021, but the 2021 NDAA added the eighth requirement – 'an assessment of the current and projected nuclear capabilities of Russia and China, and such other potential threats as the Secretary considers appropriate' – and required that the administration thoroughly brief Congress on US consultations with its allies on the NPR.[11]

The NPR has established each administration's position on the utility of the United States' nuclear triad since the process began in 1994. However, even prior to this – since the Reykjavik Summit between US president Ronald Reagan and Soviet general secretary Mikhail Gorbachev in 1987 – some detractors have challenged the notion of the US maintaining a triad.[12] While each leg of the triad plays an integral role in executing US nuclear strategy today, the three legs largely exist partly because, at the onset of the Cold War, each branch of the military wanted its own nuclear forces.[13] Though the original rationale for the triad was partly driven by intra-service rivalry, the US Army only had custody of land-based tactical and theatre nuclear weapons, with all missiles possessing ranges greater than 1,600 km operated by the USAF.

The Presidential Nuclear Initiatives (PNIs) of 1991–92 eliminated the Army's role in nuclear delivery or employment, as US president George H.W. Bush eliminated all non-strategic nuclear weapons from the US arsenal, other than free-fall bombs and submarine-launched cruise missiles (SLCM-Ns). The near elimination of the Army's role in US nuclear operations contributed to reducing the number of personnel with access to nuclear weapons by 70%.[14] This change was part of a broader project to remake US nuclear posture and policy in response to the end of the Cold War.[15] Bush also sought the ratification of the Strategic Arms Reduction Treaty (START), announcing an immediate end to the bomber alert posture and accelerating the elimination of ICBMs reduced under the implementation of START. Development of the *Peacekeeper* mobile ICBM was also cancelled and US nuclear forces were removed from the geographic combatant commands and placed under US Strategic Command (USSTRATCOM), further reducing the role of nuclear weapons in US defence.

The (first) 1994 NPR then set the US DoD on a course to 'lead but hedge', which meant that the US would continue to take steps to reduce nuclear dangers but would also maintain an arsenal suited to the threat of the resurgence of a Cold War adversary. The

NPR maintained a reduced, but still significant, role for nuclear weapons in US security strategy, describing the weapons as vital to deterring 'any future hostile leadership with access to strategic nuclear forces from acting against our vital interests and convincing it that seeking a nuclear advantage would be futile'.[16] The 1994 NPR also touted the progress the US had made on reductions to the US arsenal, including reductions to the number of delivery systems, deployed non-strategic nuclear weapons and retired weapons systems, amongst others. But the triad remained intact. In short, the 1994 NPR fundamentally 'supported the concept of the nuclear triad'.[17]

After the completion of the 1994 NPR, the US continued to examine its nuclear policy, seeking to further reduce and refine the unique role played by nuclear weapons.[18] The idea of 'tailored' deterrence emerged as the solution to managing multiple weapons-of-mass-destruction (WMD) threats and other security challenges as the focus shifted beyond Russia to potentially newly nuclear-armed states, such as Iran, Iraq and North Korea.[19] The term 'second nuclear age' emerged among policymakers, as officials worried over the potential proliferation of ballistic missiles and WMDs and scholars pushed leaders to consider the importance of 'deterrence by denial' as a hedge against the possibility of deterrence failure.[20]

In 2001, when George W. Bush took office, his administration set about remaking US security strategy on an even broader scale. This included radical changes to both deterrence strategy and nuclear policy.[21] Although the terrorist attacks of 11 September 2001 delayed the Bush administration's publication of its NPR, when it finally emerged the document unsurprisingly downgraded the threat posed by Russia and moved away from cooperative non-proliferation approaches under multilateral treaties. It focused instead on the threat of rogue states and non-state actors seeking to acquire WMDs and towards unilateral means of counter-proliferation.[22] The 2002 NPR emphasised the need for preventative and pre-emptive action against proliferators. This reflected Republican priorities to meet the challenges of the second nuclear age and reflected deep scepticism about the robustness of nuclear deterrence against new threats and the utility of arms control.[23]

The 2002 NPR also introduced the concept of a 'new triad', consisting of subsuming the three legs of the traditional 'triad' (ICBMs, SLBMs and bombers) into a wider package that included strategic offensive arms, missile defences and a revitalised defence infrastructure.[24] Additionally, the 2002 NPR revealed a commitment to maintain a nuclear posture 'second to none' in order to provide sufficient assurances to allies that the US arsenal would not be surpassed by Russia's and to dissuade China from further building up its arsenal.[25] On modernisation, the Bush administration's NPR called for the ability to 'modify, upgrade, or replace portions of the extant nuclear force or develop concepts for follow-on nuclear weapon systems better suited to the nation's needs'.[26] Implementation of this broad-reaching shake-up of an NPR was more difficult, reflecting Congress's strong opposition to Bush's national-security policy writ large. Congress repeatedly rejected nuclear-modernisation efforts, while programmes for the development of the new triad also moved slowly and remained highly controversial and the recapitalisation of the nuclear-defence enterprise continued to be overlooked.[27]

Upon taking office in 2009, US president Barack Obama sought to refocus and recentre US nuclear policy and posture. This would be reflected in the 2010 NPR's five goals: strengthening efforts to prevent nuclear proliferation and nuclear terrorism; reducing the role of nuclear weapons in US strategy; ensuring strategic stability while also reducing the number of nuclear weapons; strengthening nuclear assurance and deterrence; and maintaining a safe, secure and effective deterrent while nuclear weapons remained in existence.[28] The 2010 NPR sought to 'retain a smaller Triad' composed of the standard SLBMs, ICBMs and heavy bombers in order to 'best maintain strategic stability at reasonable cost, while hedging against potential technical problems or vulnerabilities'. This NPR unequivocally committed to retaining all three legs 'at this stage of reductions'. Pushing back on arguments that the

THE NPR
Former secretary of defense James Mattis testifies during a House Armed Services Committee following the release of the 2018 NPR. CREDIT: Samuel Corum/Anadolu Agency/Getty Images

INTEGRATED DETERRENCE
Secretary of Defense Lloyd Austin announces that the US approach to deterrence will change and will now consider multiple realms, 30 April 2021. CREDIT: US Department of Defense

land-based leg of the triad was unnecessary, the DoD insisted that ground-based ICBMs contributed to strategic stability and deterrence and, just like SLBMs, were not 'held at risk by air defenses'.[29]

Notably, under the Obama administration, the US eliminated a further nuclear capability – SLCM-N – and consolidated a number of warhead types to reduce unnecessary costs and increase efficiency. Obama was also successful in re-establishing non-proliferation and arms control as important parts of US nuclear policy, with New START ratified in 2010 and the Nuclear Security Summit process running successfully from 2010–16. As part of New START ratification, the Obama administration was required to request full funding for much-needed nuclear-infrastructure upgrades and to retain the triad for the foreseeable future. Russia rejected Obama's subsequent offer of further reductions in Berlin in June 2013, and its subsequent illegal annexation of Crimea put to rest any further arms-control initiatives or reductions in the role of nuclear weapons in US defence and extended-deterrence guarantees.

When US president Donald Trump took office in 2017, his administration's NPR maintained the nuclear policy that had been established at the end of the Obama administration. Continuity was maintained across the programme of record, and the 2018 NPR reaffirmed the need for the triad, noting that 'the triad's synergy and overlapping attributes help ensure the enduring survivability of our deterrence capabilities against attack and our capacity to hold a range of adversary targets at risk throughout a crisis or conflict'.[30] The 2018 NPR also noted that eliminating any leg of the triad could aid an adversary in its planning of an attack, as well as facilitate an adversary's concentration of resources and attention on a more limited set of targets. This is because the three legs of the triad force potential adversaries to spread their resources thinly and divert their focus of attention away from just one or two legs/systems. Additionally, the triad offers a wide range of options in planning and increased flexibility in case of issues with or failure of any one leg.[31] Trump added two elements to US force posture, seeking to reintroduce the SLCM-N and a variable-yield warhead for SLBMs, the W76-2.

As of August 2022, the Biden administration is yet to publicly release its NPR, although the US DoD has issued a limited fact sheet on the forthcoming document, which signalled the administration's desire to put its own stamp on US nuclear posture. The fact sheet employs language that indicates a shift to 'integrated deterrence'. In a speech in April 2021, US Secretary of Defense Lloyd Austin said that the US will be taking a new approach to preventing nuclear war

Figure 5.2: **Modernisation of the US nuclear triad**

NAME	RANGE (KM)	WARHEAD TYPE AND NUMBER	BASING OPTION	NUMBER OF STAGES	NUMBER OF LAUNCHERS (ESTIMATED)	INITIAL OPERATIONAL CAPABILITY
LGM-35A *Sentinel* ◦ **Type** – ICBM ◦ **Fuel type** – Solid	12,000+	NUCLEAR X 1 (POSSIBLE MIRV)	SILO	3	400	2029
UGM-133A *Trident* II D5LE2 ◦ **Type** – SLBM ◦ **Fuel type** – Solid	12,000+	NUCLEAR X 8	*COLUMBIA*-CLASS SSBN	3	280	2030s
AGM-181 Long-Range Stand-Off Weapon (LRSO) ◦ **Type** – ALCM ◦ **Fuel type** – Unknown, likely Turbofan	2,400+	NUCLEAR X 1	B-21 *RAIDER* B-52H *STRATOFORTRESS*	N/A	500	2030
B61-12 ◦ **Type** – Gravity bomb ◦ **Fuel type** – N/A	N/A	NUCLEAR X 1	B-21 *RAIDER*	N/A	480	2022

Sources: IISS; *The Military Balance 2022*; *Bulletin of the Atomic Scientists*

and that its approach to the concept of deterrence has evolved to 'integrated deterrence'. This evolved concept, according to Austin, 'rests on the same logic' of deterrence as previously defined, but now considers 'multiple realms'. US thinking on deterrence had been de-integrated at the end of the Cold War and would now be re-integrated, with full-spectrum deterrence (conventional, nuclear, missile defences, cyber and outer space) contributing to preventing attacks by adversaries.

US Targeting Plans and Posture

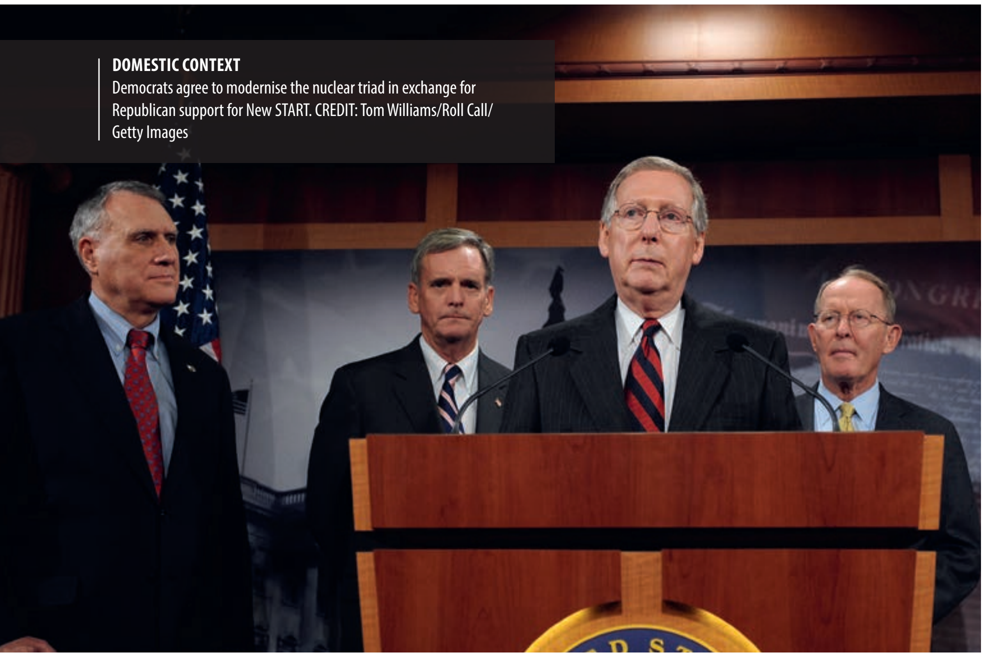
The US currently practises counterforce targeting, meaning that in the event of a nuclear war, it would use its nuclear arsenal to attack enemy military bases, forces, command-and-control centres and leadership sites.[32] This is a policy the US has maintained since the Cold War. By contrast, some states, such as China, practise counter-value targeting, meaning that, in the event of a nuclear war, the nuclear arsenal in question would be used to target population centres to inflict an unacceptable level of pain on the adversary.[33] Russia's targeting strategy, however, is believed to be a mixture of these, with clear guidance to target military infrastructure, but with contingencies for striking civilian infrastructure and, at the highest end of warfare, counter-value targeting.[34]

The US prefers counter-force targeting primarily for legal and ethical reasons: it allows the US to remain in compliance with the law of armed conflict, which requires countries at war to distinguish between military and civilian targets.[35] Counter-force strategy also permits the US to implement the nuclear doctrine of targeting an enemy's nuclear arsenal at first strike to prevent its launch and avoid mutually assured destruction. According to scholar Matthew Kroenig:

> The primary purpose of US nuclear weapons is to deter nuclear attack, but, if deterrence were to fail, the United States would not simply accept 'mutually assured destruction'. Counter-force targeting potentially allows the United States to destroy enemy nuclear weapons before they can be used against the United States or its allies, limiting damage and potentially saving millions of lives.[36]

Some analysts argue that counter-force targeting imposes sizeable quantitative requirements for the US nuclear arsenal, and therefore call for a much greater number of nuclear weapons to be targeted at military sites.[37] In addition to numerous nuclear targets, analysts assess that the US has assigned two offensive nuclear warheads to each enemy target to guarantee their destruction.[38] Calculations indicate that across China, North Korea and Russia, there are approximately 1,000 nuclear targets in total – close to half of the size of the United States' currently deployed nuclear arsenal.[39] Additionally, this number stands to increase as China appears to be expanding the size of its nuclear arsenal.[40] Some have argued, therefore, that for the US to maintain its counter-force strategy, it may need to quantitatively increase the size of its nuclear arsenal to keep pace with the quantitative developments of China's and North Korea's nuclear arsenals.[41]

Others analysts disagree, arguing that the development of more advanced space-based sensors could provide US decision-makers with more accurate targeting information that could obviate the need for the US to assign two nuclear weapons to each target and reduce the pressure to expand the size of the arsenal.[42] They argue that deciding the size of a country's own arsenal based on an adversary's only makes sense if decision-makers believe that nuclear weapons are for actually fighting wars as opposed to deterrence, and that 'the best way to get out of an arms race is by refusing to play'.[43]



DOMESTIC CONTEXT
Democrats agree to modernise the nuclear triad in exchange for Republican support for New START. CREDIT: Tom Williams/Roll Call/Getty Images

US Nuclear Modernisation

The modernisation of the United States' nuclear arsenal is currently under way. The project largely aims to upgrade the United States' ageing triad with new technology to maintain reliability, though some systems will see qualitative improvements consistent with broader US DoD efforts to offset adversary advancements and maintain a competitive edge.[44] The term 'modernisation' explicitly refers to the replacement of ageing US nuclear systems with new equipment, rather than a quantitative increase in nuclear warheads or launchers. Modernisation will update all three legs of the US nuclear triad, with 20-years' worth of replacement programmes in place for bombers and associated ALCMs, land-based ballistic missiles and ballistic-missile submarines.[45] Additionally, multiple warhead designs will undergo LEPs to ensure their reliability.

Background

The US modernisation programme largely began under the Obama administration, which originally outlined these programmes in the 'Section 1251 Report', as mandated by Congress. The mandate appeared in the 'Defense Authorization Act for Fiscal Year 2010' and required the administration to submit a report to Congress in conjunction with its submission of the New START to the Senate for ratification. The report was to describe how the administration planned to 'enhance the safety, security, and reliability of the nuclear weapons stockpile of the US; modernize the nuclear weapons complex; and maintain the delivery platforms for nuclear weapons', with ten-year budget projections.[46]

Prior to the emergence of this report requirement from Congress, Obama had committed to modernise nuclear-warhead production facilities at the US Department of Energy (DoE) in exchange for Republican support in the Senate for New START ratification.[47] New START negotiations had begun amidst a contentious domestic setting as Republican lawmakers railed against Obama's nuclear agenda and the lack of progress in updating the United States' nuclear arsenal and informed the administration that reductions in the US nuclear arsenal (via New START) would only be accepted if this was accompanied by an effort to modernise the nuclear deterrent.[48] Obama subsequently pledged to the Senate Appropriations Committee that he recognised that US nuclear modernisation required investment for the long term and a near one-to-one replacement for existing nuclear-weapons systems.[49]

Many analysts pointed to US modernisation plans and Obama's commitment to maintaining a triad as a contradiction of the declarations the US president had made earlier in his first term to reduce the role of nuclear weapons in US defence policy, as well as to strive for nuclear disarmament.[50] This dual commitment led to a debate about what degree of 'modernization' was actually needed.[51] At least three studies were conducted on the modernisation of the US nuclear arsenal. A 2009 report by the Congressional Commission on the Strategic Posture of the United States found that the alternative to modernisation – the utility of LEPs – to extend the life of the current arsenal of weapons indefinitely was limited because such a 'remanufacturing' process would introduce greater uncertainty about the expected operational reliability of the weapons.[52] Proponents of modernisation argue that the safety and reliability of these weapons are essential to providing deterrence for the US as well as extended deterrence for its allies around the world. Losing confidence in a US nuclear umbrella composed of ageing weapons might lead these allies to pursue their own nuclear weapons.[53] However, a technical report authored by JASON in 2009 found that LEPs could reliably extend the lifetime of current nuclear weapons for decades.[54] The same study found that the plutonium cores of existing nuclear weapons were usable for another century or more and that new production would cause the US to lose credibility on the non-proliferation efforts stipulated by its signing of the Treaty on the Non-Proliferation of Nuclear Weapons.

Finally, a 2014 study conducted by the USAF reviewed alternatives to the ICBM force and recommended developing a new ICBM, noting that it would cost less to build and would be less complicated than extending the life of existing equipment. In addition, the report assessed that an evolving threat environment would mean that upgraded *Minuteman* III missiles would not meet future requirements, even if they were equipped with new components. Following the USAF's decision, the DoD stopped supporting vendors who could make 1970s-era spare parts for *Minuteman* III, thereby simultaneously reducing the capacity of manufacturers to produce new parts and driving up costs.

Ultimately, the real source of the modernisation plan was the ageing arsenal itself: the SSBNs had a lifespan limited by their hull life and reactor core and had to be replaced by the 2030s. The *Minuteman* III was slated to be replaced, beginning in 2018, because of the limited numbers of test assets and the ageing rocket motors. Simultaneously, bomber-replacement plans were driven by the need for a larger force of conventional bombers for regular war fighting.[55]

Modernisation by Triad Leg

Land

Today, the USAF continues to develop a new type of ICBM to replace the *Minuteman* III missile.[56] The new ICBM received its official name, the LGM-35A *Sentinel*, in April 2022.[57] The product of digital engineering, *Sentinel* will be a three-stage solid-fuel missile which will likely have a range similar to that of the outgoing *Minuteman* III (roughly 12,000 km). *Sentinel* has been designed to 'incorporate digital engineering technologies and employ a modular open system architecture [to adapt to evolving threat environments], which will provide interoperability and reduce lifecycle costs'.[58] The new missile system will also have modernised command-and-control technology to reduce notification time to launch and facilitate quick engagement in the event of a surprise attack. The USAF expects an initial operational capacity consisting of nine missiles to be achieved by 2029, with a total deployment of 400 expected by 2036.[59] In FY2023, the Biden administration allocated US$3.6 billion in its budget request for this programme.[60]

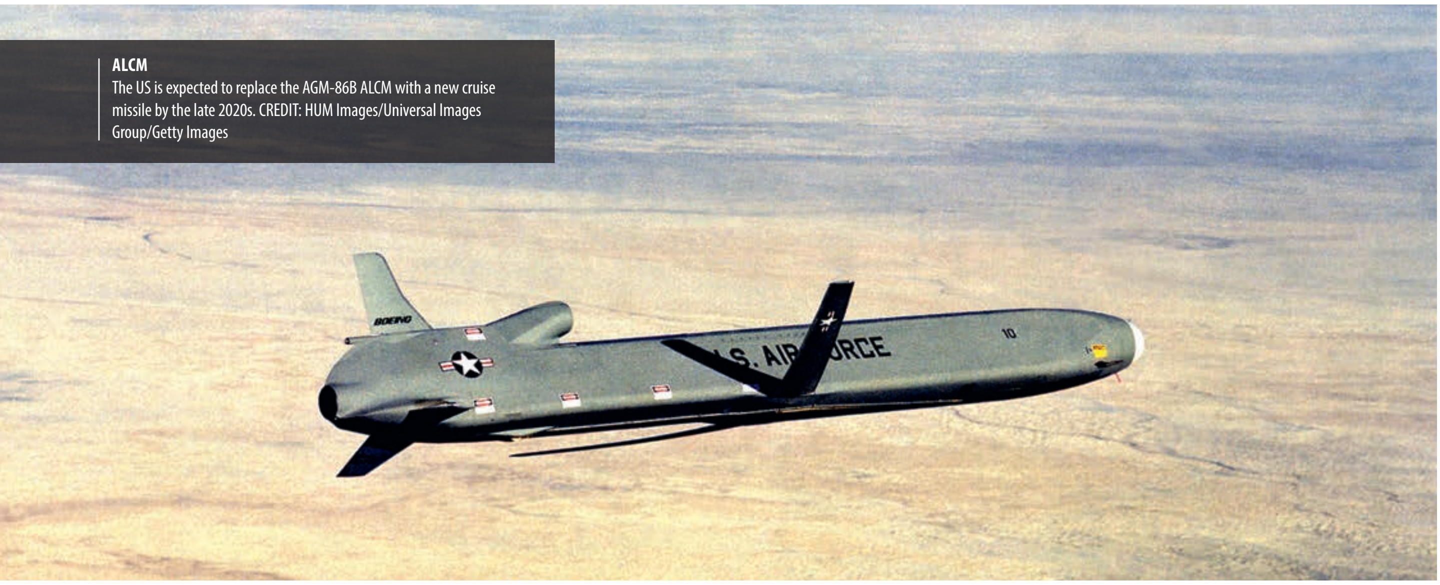
Additionally, the US National Nuclear Security Administration (NNSA) within the DoE is currently developing a new warhead, the W87-1, designed specifically for deployment on *Sentinel*. The W87-1 will have a yield of 475 kt and will replace the W78 warheads that are currently paired with *Minuteman* III missiles.

Sea

The USN is planning to retire its current fleet of 14 *Ohio*-class SSBNs from 2027 onwards, replacing them with 12 new *Columbia*-class submarines. The first of these *Columbia*-class boats is slated to conduct its first deterrent patrol in 2031, with the remainder projected to be delivered by 2042. While 14 *Ohio*-class boats were needed by the USN to meet its requirement of having ten boats operational at any one time, the shorter midlife overhauls of the *Columbia* class means that more boats will be available during the course of the boat's life cycle, therefore meaning that a smaller number is needed. The cost for 12 new *Columbia*-class SSBNs is estimated to be US$139bn, of which the Biden administration requested US$6.3bn in the FY2023 budget.[61] Each *Columbia*-class boat will be equipped with 16 SLBM tubes, four fewer than the current SSBN. Like the *Ohio* class, the successive *Columbia* class will also utilise the *Trident* II D-5LE SLBM. A potential second LEP, known as the D-5LE2, aims to ensure *Trident* will remain operational until the 2080s.

According to USN officials, building these boats is the USN's top-priority programme and the USN is devoting

SSBN
The US Navy is expected to acquire 12 *Columbia*-class SSBNs from 2027–42.
CREDIT: US Department of Defense



ALCM
The US is expected to replace the AGM-86B ALCM with a new cruise missile by the late 2020s. CREDIT: HUM Images/Universal Images Group/Getty Images

considerable time and attention to it.[62] However, their development is fraught with potential complications. The 2031 delivery date leaves little room for error, technical challenges or other unexpected delays. As the cost of the programme has increased over time, concerns have arisen that other programmes will have to suffer reduced budgets to keep the *Columbia*-class programme on track financially. Both the Congressional Budget Office and the Government Accountability Office have determined that the risk of cost growth for the *Columbia*-class programme is high. Additionally, the programme is tasking the industrial base in the extreme, as the USN is also currently trying to produce its nuclear-powered *Virginia*-class cruise-missile submarines (SSN-774s).[63]

In addition to developing new platforms and delivery vehicles, the USN is also modernising its nuclear warheads for delivery by SLBMs. The NNSA has embarked on an LEP for the SLBM's W76 warheads, with the intention of producing a low-yield design known as the W76-2. A small number of these were provided to the USN in 2019. In response to safety concerns about its W88 warheads, the system is being upgraded.

The NNSA is also developing a new warhead to eventually replace its older W76 and W88 warheads. The new warhead, known as the W93, is expected to be deployed between 2034 and 2036. Notably, the W93 is the product of a UK–US collaboration, since both nations are armed with the *Trident* II D5 missile. Though no specific yield information has been released, the W93 is likely to be higher yield than the W76-2.

Air

The USAF is currently developing at least 100 B-21 *Raider* bombers to replace its existing fleet of B-2 bombers. The B-21 will form the updated air leg of the United States' nuclear triad, although, like the B-2, it will also be used for conventional missions. For the latter role, it will employ a broad mix of stand-off and direct-attack munitions. The B-21 could also potentially replace the USAF's B-52 in the future. The B-21 aircraft is expected to be in service by the mid-2020s.[64] The Biden administration requested US$5bn in the FY2023 budget for the aircraft's development.[65]

For the B-21's nuclear mission, the USAF will replace the ageing AGM-86B ALCMs with a new cruise missile known as the AGM-181 Long-Range Standoff Weapon (LRSO). Unlike the ALCM, which could only be launched from the B-52, the LRSO is expected to be launched from several different types of aircraft. Although there is very little information available to date on the system's design, the missile will likely have a range comparable to that of its predecessor.[66] The Biden administration has requested US$1bn for the LRSO's development in the FY2023 budget.[67] The LRSO is expected to be operational by the late 2020s.[68]

As well as developing new stand-off capabilities, the USAF plans to improve its existing free-fall nuclear equipment. The B61 nuclear gravity bomb is currently undergoing an LEP at an estimated cost of US$8.3bn, with a new model, the B61-12, slated for deployment in 2022. The B61-12 gravity bomb has a variable yield, which can be adjusted to range from 0.3 to 340 kt.[69] The NNSA plans to retire the B83-1 bomb, which has the largest megaton yield in the US nuclear arsenal.

US Conventional-missile Programmes

Since the collapse of the Intermediate-Range Nuclear Forces Treaty (INF Treaty) in 2019, the US has been developing several new types of ground-launched conventionally armed ballistic and cruise missiles across the agreement's previously restricted range of 500–5,500 km. The Trump and Biden administrations' post-INF strategies are intended to counter China's and, to a lesser extent, Russia's advantages in this area.[70] This shared ambition reflects the sentiment originally expressed in the 2018 National Defense Strategy (NDS), warning that the US was facing the 're-emergence of long-term, strategic competition between nations', and that it required responses such as 'building a more lethal force'.[71] Once developed and deployed, these new conventional systems will expand US missile-launcher options from primarily air- and maritime-delivered munitions to include multiple types of ground-launched systems. This diversification will provide US forces with improved flexibility and targeting options and stands to complicate peer adversaries' planning and operations in a conflict. Some of these new systems will also extend the range and accuracy of the United States' conventionally armed precision-strike systems and provide branches of the US armed forces with new types of equipment that may act as force multipliers.

While the US is making steady progress in developing these systems, their deployment might prove to be a greater challenge. In the Asia-Pacific, some US allies, including Australia and South Korea, have downplayed the possibility of hosting these INF-range missiles in order to avoid antagonising China.[72] Unless the US can persuade its allies to host some of its new shorter-range systems, they may only then be deployed to US territories in the region, such as Guam, as many have insufficient reach to strike targets in eastern China. As such, their overall use and impact would be limited. By contrast, in-development air- and sea-launched systems will not be as restricted due to the mobility of their launch platforms. Meanwhile, NATO's decision at the 2022 Madrid Summit to strengthen its deterrence and defence capabilities might mean that the deployment of these types of land-based systems in Europe will be more politically feasible, given NATO members' determination to better deter Russia following its 2022 invasion of Ukraine.[73]

Figure 5.3: **US conventional missiles currently deployed and under development**

Sources: IISS; *The Military Balance 2022*

PrSM
PrSM will replace ATACMS and provide the US with an improved conventional ground-launched ballistic missile. CREDIT: United States Army Acquisition Support Center

'Traditional' Conventional Ballistic and Cruise Missiles

The shortest-range ground-launched ballistic missile that the US is developing is the Precision Strike Missile (PrSM), designed by Lockheed Martin. The PrSM will replace the US Army's existing surface-to-surface ballistic missile, the Army Tactical Missile System (ATACMS). In addition to the Army, the United States Marine Corps will also be equipped with PrSMs, providing it with a long-range strike capability for the first time.[74] The PrSM will have greater utility than ATACMS, as the addition of a multi-mode seeker means it will be able to identify targets at long range, providing it with a flexibility to strike both fixed and moving land and maritime targets.

Although the PrSM and ATACMS utilise similar warheads, the PrSM's initial expected range of 499 km means it will have at least a 199-km range increase over ATACMS.[75] This might be extended even further in the future: the PrSM's original range was designed to comply with INF Treaty restrictions that limited the deployment of Russian and US ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 km.[76] However, after the United States' withdrawal from the agreement in 2019, Lockheed Martin announced it is seeking to develop an extended-range system that could possibly increase the missiles' range by a further 500 to 1,000 km.[77] In the European theatre, an extended-range PrSM would outrange Russian *Iskander*-M (RS-SS-26 *Stone*) short-range ballistic missiles (SRBMs) and provide operators with the ability to strike potential targets outside the range of Russian surface-to-surface missile forces based in Kaliningrad or possibly Belarus.[78] Should the US be able to secure basing options with a partner state in East Asia – possibly Japan – an extended-range PrSM would provide the US with new targeting opportunities, from ground-launched platforms, in North Korea and limited areas of eastern and northeastern China.[79]

Like the ATACMS, the PrSM will be launched from the US Army's M142 High-Mobility Rocket Artillery System (HIMARS) and the M270A1 Multiple Launch Rocket System (MLRS). It is possible that the PrSM will be launched in the future from an uninhabited system known as the Autonomous Multi-Domain Launcher.[80] Advantageously, the PrSM has smaller dimensions than the ATACMS, meaning that two PrSMs can be fitted into each HIMARS launch pod, as opposed to just one ATACMS. Likewise, the M270A1 MLRS will be able to launch four PrSMs, rather than two ATACMS.[81] The Army has plans to field the first generation of PrSMs in 2023 and the extended-range version by 2027.[82]

For longer-range targets, the US Army is pursuing the Mid-Range Capability (MRC) system, also known as *Typhon*.[83] The MRC will utilise ground-launch adaptions of two existing missiles: the *Tomahawk* land-attack cruise missile and the SM-6. The *Typhon* is being developed by the Army's Rapid Capabilities and Critical Technologies Office to fill a capability gap identified in the 2020 strategic-fires study. By adapting existing missiles and launch platforms, the Army expects to deploy the *Typhon* system by 2023.[84]

Major Hypersonic Programmes

The US has a long-harboured, if sporadic, interest in very-high-speed cruise-missile and glide-vehicle technologies.[85] Recently renewed attention has been prompted by the development of comparable technologies by China and Russia, and by technology developments that promise, finally, to move designs from experimental hand-builds in the laboratory to systems that can be manufactured in volume with an operational utility. 'Hypersonics' was one of three defence-specific technology areas highlighted by US Under Secretary of Defense, Research and Technology Heidi Shyu in February 2022 when laying out the National Defense Science and Technology Strategy.[86] Reflecting both this prioritisation and concerns over developments among potential adversaries, the Biden administration requested a US$1bn increase in research funding for hypersonic-cruise-missile and boost-glide systems in the FY2023 budget, compared to the FY2022 figure of US$3.8bn.[87]

Alongside national efforts, Washington is also pursuing cooperative developments with allies internationally. Shyu told the Senate Armed Services Committee that 'we are working with the Australians in developing a hypersonic cruise missile'.[88] While the first initiative under the banner of the Australia, United Kingdom and United States (AUKUS) pact was to explore providing nuclear-powered submarines to the Royal Australian Navy, seven months later it was made public that the pact would also be used for cooperation on hypersonic cruise missiles and on defence options against very-high-speed weapons.[89]

While there remains ambiguity as to whether Beijing and Moscow will eventually field conventional *and* nuclear-armed hypersonic cruise missiles and boost-glide systems, Washington has so far maintained that any system it would introduce would be conventional only.[90] The USAF, however, has been examining an

CPS/LRHW
The US Army and US Navy are developing a HGV jointly for their respective armed services. CREDIT: US Department of Defense

ARRW
The USAF's AGM-183A ARRW will be launched from the B-52H *Stratofortress* bomber. CREDIT: US Air Force

intercontinental-range glide vehicle with the interested agency, the US Air Force Nuclear Weapons Center, prompting questions given that Washington was adamant that such a class of weapons would be conventional only.[91] The USAF has also been looking at very-long-range boost-glide systems as part of the US Armed Forces' broader Conventional Prompt Global Strike effort.[92]

While the US military has not yet committed to any procurement programme, it is primarily interested in the utility of conventionally armed very-high-speed weapons to counter certain classes of high-value targets, rather than as a nuclear-armed weapon for deterrence. Washington's insistence that its interest is in conventionally armed systems may well be intended to address concerns of possible warhead ambiguity, which might court destabilising actions in the event of a conflict.

US Navy

The USN, like the USAF, has a history of research into conventionally armed cruise missiles capable of travelling at supersonic speeds. The subsonic Raytheon RGM/UGM-109 *Tomahawk* has provided the service with a ship- and submarine-launched land-attack capability since the 1980s. More recently, this capability has been complemented by the air-launched Lockheed Martin AGM-158 Joint Air-to-Surface Standoff Missile (JASSM). In the late 1990s, consideration was given to a project known as *Fasthawk*, which explored the use of elements from the *Tomahawk* missile rehoused in a supersonic airframe and propulsion combination.[93] In the early 2000s, the USN worked on the *Revolutionary Approach to Time Critical Long-Range Strike* (RATTLRS) to develop a 1,000-km-class missile with a maximum speed of Mach 4.[94] The programme, however, did not move beyond the technology-demonstration stage. Further to this, at the beginning of the 2000s the USN collaborated with the USAF on the Joint Supersonic Cruise Missile (JSSCM) with a similar performance requirement to RATTLRS.[95] Unlike the latter, which was designed around a turbojet, the JSSCM was designed to use a ramjet sustainer. The project was joint, not only in terms of the air force and navy, but also in its inclusion of the UK.

None of the USN's efforts in the 1990s and 2000s led to a high-speed cruise missile entering service. The USN is now, however, working on the Hypersonic Air-Launched Offensive Anti-Surface Warfare (HALO) missile, with an ambition to begin to field the weapon shortly before the end of the 2020s.[96] More immediately, perhaps, the USN has funded Boeing to work on a technology demonstrator dubbed 'Supersonic Propulsion Enabled Advanced Ramjet', or SPEAR.[97] This, again, is for an ALCM design and may be a hedge against delays to HALO.

In addition to hypersonic cruise missiles, the USN is also collaboratively developing with the Army a hypersonic boost-glide vehicle (HGV) known as the Common-Hypersonic Glide Body (C-HGB). This programme is expected to yield a conical-shaped HGV design that both branches of the armed services can utilise, albeit with individual weapons systems and launchers that are tailored to their respective requirements.[98]

The USN programme, known as Conventional Prompt Strike (CPS), is expected to reach initial operating capacity with the USN's *Zumwalt*-class destroyers by 2026 and *Virginia*-class submarines in 2028.[99] While the range of CPS has not been confirmed, defence officials have stated that the Army's corresponding system will have a range greater than 2,775 km.[100] Given these systems will use the same booster, glide body and other technologies, it is likely the CPS will have a similar range. This would give the USN the ability to launch precision strikes against targets in eastern China from the Second Island Chain or against Russia from, presumably, the North Sea and the Norwegian Sea. CPS, like all known US Mach 5+ technologies, will be armed with a conventional warhead.

Although the deployment of CPS will improve the USN's long-range precision-strike capabilities, its planned introduction will create trade-offs on expected launch platforms by reducing the amount of magazine space available for other types of systems. The US currently operates 20 *Virginia*-class submarines across four different versions (Block I–IV), each of which is equipped with a vertical launch system (VLS) known as the Virginia Payload Tube (VPT). Each VPT can store six RGM/UGM-109 *Tomahawk* land-attack cruise missiles (LACMs), with a total of 12 LACMs per boat. CPS has a larger diameter when compared with *Tomahawk* (34.5 inches versus 20.4 inches), which will mean the USN will have to reduce the number of LACMs each submarine will carry beyond a 1:1 replacement, should they be equipped with CPS. If Block I–IV variants of the *Virginia* class are equipped to carry CPS, it is unlikely each boat will be able to carry substantial numbers of the missile – possibly as few as one or two.

The USN is currently developing a larger version of the *Virginia* class, known as the Block V, which will have an additional VLS section known as the Virginia Payload Module, thereby allowing newer *Virginia*-class boats to carry more missiles. While this will likely mean the Block V will have a greater capacity for carrying more CPS systems, the cost of developing and producing the missile, as well as the trade-offs associated with reducing the number of LACMs aboard each boat, means it is likely each submarine will only be equipped with fewer than ten CPS systems. Likewise, *Zumwalt*-class destroyers will also be equipped with limited numbers of CPS, due to space constraints that the USN is attempting to partially offset by removing gun mounts for the destroyers' two 155mm deck guns.[101]

US Air Force

In the unclassified arena the most prominent USAF project is the Hypersonic Air-Breathing Concept, developments of which are supporting its Hypersonic Attack Cruise Missile (HACM) ambitions.[102] HACM is aimed at developing a comparatively compact air-launched scramjet-powered (supersonic combustion ramjet) weapon, which is a variant of a ramjet air-breathing jet engine in which combustion takes place in supersonic airflow, that can be carried by both combat aircraft and bombers. As with much that is related to very-high-speed-weapons research, there remains a question as to the extent to which additional developments are being pursued in the classified realm.

Unlike the USN and Army, the USAF is developing a stand-alone hypersonic glide vehicle design which is known as the AGM-183A Air-Launched Rapid Response Weapon (ARRW). Developed by Lockheed Martin, the ARRW is a two-stage air-launched HGV that will be armed with a conventional warhead. Four ARRWs will be able to be mounted on external pylons on the B-52H *Stratofortress* bomber; however, the USAF plans to also integrate the missile onto the B-1B bomber and the F-15E *Strike Eagle*.[103] The maximum speed of the glider is unknown and its maximum range is uncertain, but it is believed to be greater than 1,600 km.[104] The Biden administration requested US$115 million for the ARRW programme for FY2023, which had faced an uncertain future after successive launch failures in 2021.[105]

US Army

The US Army's programme within the broader CPS programme is known as the Long-Range Hypersonic Weapon (LRHW) programme or *Dark Eagle*. It shares a C-HGB with the USN but the Army's version will use a different launch platform consisting of an M983 truck and trailer, each of which can hold two missiles in launch canisters.[106] The Army plans to deploy four M983s alongside a command vehicle for an eight-missile battery. The LRHW's expected 2,775-km range will extend the US Army's long-range precision-strike capabilities over the range of its current longest-range surface-to-surface ballistic missile, the ATACMS, by nearly tenfold. The Army is seeking to attain a 'residual operational capability by the end of fiscal year 2023'; however, whether this goal is attainable depends on the meeting of the joint CPS–LRHW programme's tight deadline.[107]

Hypersonics, Mission and Controversy

Some analysts have noted that the US DoD has not designated which missions it would use hypersonic weaponry for and therefore appears to be pushing for their development without considering whether existing weapons meet US military requirements.[108] Others have suggested that the

STRATEGIC STABILITY
US and Russian concepts differ in terms of breadth. CREDIT: Demetrius Freeman/The Washington Post/Getty Images

COMPETITION
Trilateral competition will drive arms racing. CREDIT: GREG BAKER/ AFP/Getty Images

US is developing these systems as part of an arms race with China and Russia.[109] Still others have charged that these factors are irrelevant: US missile development is behind Russia's and China's and must catch up as soon as possible.[110] US civilian and military decision-makers have since taken steps to identify hypersonics as a critical technology that could be used to strike time-sensitive and high-value targets, while policymakers have continued to emphasise that the US must engage in 'effective competition' with China and Russia in Mach 5+ technology, lending credence to the suggestion made by some analysts that the fear of a technology gap is partly pushing US decision-making processes.[111] One impact of missionless development could be a lack of metrics for success. One scholar wrote: 'Without a clear picture of the missions for which these weapons might be acquired, there is no yardstick against which to judge their effectiveness.'[112]

Nevertheless, *potential* missions could include:

- providing the US with enhanced deterrence-by-denial options, for instance, by striking high-value and time-sensitive targets such as ballistic-missile launchers before an adversary could launch a nuclear attack against either the US or its allies;
- providing the US with enhanced deterrence-by-punishment options against an adversary in the event that they used nuclear weapons in a limited strike against a US partner;
- countering anti-access/area-denial capabilities to ensure US freedom of movement in contested maritime areas in the event of a conflict;
- conducting counter-terrorism operations to destroy high-value targets.

Strategic Stability

The US conception of 'strategic stability' stands to change with recent events and technological developments, including hypersonic weapons.

US Interpretation of 'Strategic Stability'

According to the fact sheet released by the US DoD on the Biden administration's NPR, strategic stability is accomplished via a combination of nuclear weapons and attempts to limit the need for arms racing through risk reduction and arms control.[113] A recent survey of US experts revealed that most of them associated 'strategic stability' with 'a state of relations that minimizes the risk of escalation and maximizes predictability'.[114] Interestingly, that study found that US experts typically interpret strategic stability in a much narrower way than their Russian counterparts. US experts tend to focus solely on military and technical factors that impact deterrence and may lead to destabilising changes in nuclear capabilities, postures and doctrines.[115] In particular, US experts believe that the weapons and technologies that pose a risk to strategic stability are hypersonic weapons, offensive cyber operations, weapons for attacking outer-space objects and long-range precision-strike weapons – the mirror image of integrated deterrence. US experts also tend to agree that emerging technologies are making it difficult to maintain a state of strategic stability. Russian experts, by contrast, take a broader view, one that includes political, military and economic relations in their interpretations of strategic stability.[116]

Though they have since been suspended due to Russia's war of aggression against Ukraine, a series of Strategic Stability Dialogues (SSDs) were embarked on by the US and Russia in 2021. In the countries' joint statement, they indicated the shared notion that the purpose of the dialogues, and thus of strategic stability, was to ensure predictability and reduce the risk of nuclear war.[117] Additionally, the dialogues aimed to promote future arms-control and risk-reduction measures.

Minimising Stability: Remaining Competitive

Many scholars have written about the impact of hypersonic weapons on strategic stability.[118] Others have described how hypersonics compress decision-making time and increase counter-force temptations due to their precision targeting.[119] Still others have discussed the heightened ambiguity hypersonic missiles bring to military actions.[120] Most agree that there are no easy or straightforward solutions in sight.

The idea of constraints on hypersonic systems arose during New START negotiations, when Russia brought up the issue of HGVs constituting a new kind of strategic offensive arm that should trigger negotiations about how the treaty would regulate them. However, the US rejected this position on the grounds that non-ballistic missiles should not be included in the agreement in order to protect its right to develop a conventionally armed HGV.[121]

While HGVs that are deployed atop ICBMs are covered by New START, the most proximal challenge of incorporating HGVs into New START is that the treaty does not cover missiles that fly on a ballistic trajectory for less than 50% of their flightpath.[122] Given that several states, including China, North Korea and Russia, are developing or have already deployed HGVs, New START's bilateral format and narrow focus on strategic-range systems may mean that the US will have to rethink its position on the inclusion of HGVs in the future. For example, the US could alternatively consider a more ambitious multilateral agreement that would ban or place a moratorium on developing strategic-range systems to prevent an arms race and further disruption of strategic stability. However, considering that securing a legally or politically binding agreement would be extremely difficult given the current relations between the US and China and Russia, international transparency and confidence-building measures might be a more practical alternative for Washington to pursue instead. The US *could* propose a dialogue to include Russia and China, offering sufficient incentives to bring both to the table. Russia and China are more likely to engage in arms control if the US comes to the table with concrete, well-drawn-out proposals rather than broad or vague goals.[123] For example, the agenda for these dialogues could include:

- transparency on the number and types of hypersonic weapons deployed and under development;
- the exchange of information on how these weapons fit into nuclear and conventional war-fighting doctrine;
- creating a clear separation between nuclear and conventional launchers, while agreeing to refrain from using nuclear-designated launchers for conventional hypersonics to avoid a false nuclear alarm;
- providing the exchange of data for acquisitions and/or deployments of hypersonics;
- allowing observers to be present at military exercises that include hypersonics;
- placing restraints on sea-based tests.

Russian and Chinese Competition and US Decision-making

Russia's war against Ukraine and China's destabilisation of Taiwan have provided evidence that both countries may yet become more aggressive than predicted, possibly forcing greater changes in US decision-making. The delayed release of the unclassified 2022 NPR, for instance, appears to be partially linked to Russia's invasion of Ukraine.[124] The increasingly close relationship between Russia and China is a cause of serious concern for the US, and how this relationship develops will also likely impact US policy. Furthermore, the historic bilateral competition between Russia and the US has taken on a new configuration, and US officials have stated that it will have to face two peer nuclear-capable competitors simultaneously.[125] While the United States' 2018 NDS named China as a peer competitor in equal standing with Russia in describing a return to great-power competition, some analysts have charged that the US lacks a contingency plan in the event that it should find itself confronting *two* nuclear superpowers concurrently and have proposed that the ability of the US to win or even just survive

CPS/LRHW
Despite mechanisms to incorporate new technologies, it is likely that some Russian systems will remain outside of the New START agreement.
CREDIT: Alberto Pizzoli/AFP/Stringer/Getty Images

a nuclear war against both adversaries is uncertain.[126] Despite this, changes to the United States' nuclear posture occur slowly, with even incremental changes taking time. This section addresses select points of departure from what has been considered the traditional security environment and proposes possible future alterations to US nuclear policy in response.

Chinese and Russian Modernisation

The modernisation of nuclear forces creates two different weapons categories: 'new types' refers to the next-generation version of a missile that then falls under arms-control-treaty limitations as a new type of an existing missile.[127] 'New kinds', however, refers to completely new weapons systems that do not have a predecessor under treaty limitations. At the tail end of the New START negotiations, knowing that new missile technologies were in development, the US and Russia wrestled with what to do about these.[128] While US negotiator Rose Gottemoeller insisted that the US and Russia needed to see eye to eye on what to do about these new kinds, Russian negotiator Anatoly Anatov insisted otherwise, as he, according to Gottemoeller 'couldn't imagine it being a problem during the life of the treaty'.[129] Eventually, the US and Russia agreed to take 'new kinds' of weapons of concern to the treaty's implementation body, the Bilateral Consultative Commission – knowing that was a partial solution: '[F]or a new kind to be brought under the limits of New START, the country developing it would have to be willing to make it subject to the treaty.'[130] New START was, in a way, designed to be flexible, dynamic and adaptable enough to accommodate certain novel technologies. Article V of the treaty states:

> When a Party believes that a new kind of strategic offensive arm is emerging, that Party shall have the right to raise the question of such a strategic offensive arm for consideration in the Bilateral Consultative Commission.[131]

Moreover, the US was aware of ongoing Russian development of a number of new types and new kinds of systems. This included an HGV known as *Avangard* (RS-SS-19 Mod 4); a new ICBM, *Sarmat* (RS-SS-X-29); an air-launched ballistic missile, *Kinzhal* (RS-AS-24 *Killjoy*); a nuclear-powered and nuclear-armed cruise missile, *Burevestnik* (RS-SSC-X-09 *Skyfall*); and a claimed hypersonic cruise missile known as *Tsirkon*. In 2019, Russian President Vladimir Putin and Foreign Minister Sergei Lavrov stated that *Avangard* and *Sarmat* would be accountable under New START.[132] *Burevestnik* and *Tsirkon*, however, would remain outside the scope of the treaty, but in any case were not scheduled to be deployed until after New START would go out of force in 2026. Suspicious of the Russians and their development of treaty-evading systems, Gottemoeller writes:

> Another set of questions emerged around whether the Russians were up to something in the secret development of new nuclear weapon systems. I can say that in 2010, we had no evidence that the Russians were developing and preparing to deploy the ground-launched intermediate-range cruise missile that later became a violation of the INF Treaty. Its nature as a ground-launched system only became clear in 2011, after New START entered into force. Likewise, the new systems that President Putin advertised in his famous speech of March 2018 were either clearly accountable under the treaty—for example, the Sarmat heavy ICBM—or would not be ready for deployment during the life of the treaty.[133]

However, Gottemoeller and others were optimistic there would be a cooperative solution to this once New START had been signed:

> Since we were intent on negotiating another treaty after New START had entered into force, we believed that we would have ample opportunity to work on such issues. Even absent a new negotiation, we knew that New START provided the mechanism for us to question the Russians about any new kinds of weapons that they might develop during the life of the treaty.[134]

Indeed, in 2021, under the Biden administration, the US and Russia returned to the negotiation table for SSDs that were designed to lay the groundwork for future arms-control and risk-reduction measures. The dialogues kicked off with a meeting between Biden and Putin in June of that year and the two leaders issued a statement at the meeting's conclusion, reaffirming the shared principle that a 'nuclear war can never be won and must never be fought', and noting that 'even in periods of tension', the US and Russia 'are able to make progress on our shared goals of ensuring predictability in the strategic sphere, reducing the risk of armed conflicts and the threat of nuclear war'.[135] At the time, Biden noted during a press briefing: 'We'll find out within the next six months to a year whether or not we actually have a strategic dialogue that matters.'[136]

Meanwhile, China and Russia continue to evolve their nuclear-force structures and postures, and the threat from China's growing nuclear stockpile is likely to continue to catalyse change within the US nuclear apparatus. US Admiral Charles Richard, commander of USSTRATCOM, offered testimony before the House Armed Services Subcommittee on Strategic Forces on 1 March 2022, commenting extensively on the serious challenge of deterring two peer competitors at the same time, while discussing the urgent need for nuclear modernisation.[137]

Richard has also offered his perspective on just how complex the challenges are and therefore resistant to simple solutions:

> Measuring a stockpile is a very crude way to describe what a nation can and can't do. There's much more to it. It's delivery systems, command-and-control, readiness training. And I don't have the luxury of deterring one country at a time, right? I have to deter all countries, all the time, in order to accomplish my mission sets.[138]

Nevertheless, change is essential: Richard noted that the 'bolt from the blue' scenario, the large-scale attack without warning, that at one time drove US nuclear planning, is highly unlikely, and, as a result, 'we have to be careful when we make future decisions that we don't forget how we got here, lest we return ourselves to a world we don't want to be in'.[139] China's People's Liberation Army and its full modernisation, designed to produce a 'world class military' by 2049, are likely to continue to drive changes in US nuclear policy and posture. Some US analysts, however, have pushed back on Richard's testimony, arguing that the admiral offered 'curious claims and used misleading data', particularly in overstating threats from Russia and China, and understating the significance of the massive modernisation programmes currently under way in the US.[140]

Liminal Warfare

In addition to evolving military hardware, potential destabilisation and a second peer nuclear competitor, recent events and interactions with both Russia and China have forced the US to consider 'liminal warfare' and how it should impact planning and decision-making. Liminal warfare is defined as 'the integration of political, economic, legal, military, intelligence, and cyber into a single seamless mix of manoeuvre activity focused on shaping of operations with the adversary before an operation is launched'.[141] Russia has already evolved the way it conducts war in alignment with this concept:

- Prior to its invasion of Crimea in 2014, Russia targeted Germany by manipulating the prices of Russian oil and gas to create a choice of energy or nothing. This was designed to forestall a reaction by NATO to the Russian invasion and amounted to a combination of political and economic warfare.[142]
- Russia also launched cyber attacks on Ukraine's government websites in February 2022 prior to its second invasion. Poland and Lithuania were both the target of a massive influx of undocumented immigrants coming over their shared borders with Belarus (an ally of Russia) to strain military resources and distract from the events in Ukraine.
- Russia has also used disinformation operations in its war effort, running campaigns on social media prior to and during the invasion of Ukraine designed to create political destabilisation.
- Russia has continued to employ economic coercion targeted at Europe, drastically increasing the price and manipulating the supply of Russian oil and gas, which had constituted 40% of the European Union's energy imports.

For the US, this means that integrated deterrence could plausibly evolve to counter Russian actions with an effective deterrence ideology, while drawing on the strengths that come from having capable allies.[143]

While the Biden administration's NPR still had not been published as of August 2022, under the previous administration the possibility of a great-power war in Eastern Europe between NATO and Russia or between the US and China over Taiwan affected US nuclear strategy. For example, the Trump administration explored 'limited' nuclear options consisting of small nuclear strikes to deter Russian or Chinese conventional aggression or to deter nuclear threats. To wit, the Trump administration sought to develop nuclear-armed SLCM-Ns and SLBMs with very-low-yield nuclear warheads.[144] The Trump administration's 2018 NPR outlined the need for these supplemental capabilities for:

- deterring 'de-escalation' strikes by Russia in light of Russia's 'escalate to de-escalate' strategy, whereby Russia uses aggressive threats, including threatening the use of limited nuclear weapons, to de-escalate conventional conflicts;
- offsetting a qualitative imbalance in non-strategic nuclear weapons with China;
- providing assurances to allies in Europe and the Indo-Pacific; and
- to hedge against Russian exploitation of the elimination of most types of non-strategic nuclear weapons by the US after the Cold War to pursue their campaign in Ukraine with limited military repercussions from the US or NATO.

However, the Biden administration eliminated funding for the SLCM-N. During his campaign, Biden promised to 'renew our commitment to arms control for a new era'.[145] He said he would try to revive the Joint Comprehensive Plan of Action (or 'Iran deal'), extend New START and jump-start a new campaign with other nuclear-weapons states such as China to denuclearise North Korea. While on the campaign trail, Biden also committed to reducing the role of nuclear weapons and highlighted his belief that the sole purpose of US nuclear weapons is to deter, or to retaliate, if necessary, against a nuclear attack.[146] More recently, and since the outbreak of the 2022 Russia–Ukraine war, Biden has said that 'the United States would only consider the use of nuclear weapons in extreme circumstances to defend the vital interests of the United States or its allies and partners'.[147] Ultimately, the fact sheet on the NDS referred to the 'fundamental role' of nuclear weapons in deterring an attack – not the 'sole purpose' doctrine Biden espoused on the campaign trail.

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Missile Acquisitions and Developments

CHAPTER SIX

What are popularly referred to as 'ballistic' missiles continue to be the primary delivery mechanism for nuclear warheads and remain central to the strategic arsenals of the nine nuclear powers. Conventionally armed close- and short-range ballistic missiles (respectively, CRBMs and SRBMs) have, in recent years, also gained currency, with renewed interest in their development or acquisition. Conventionally armed land-attack cruise missiles (LACMs) have spread more widely, despite decades of arms-control efforts. France, Pakistan, Russia and the United States also field nuclear-armed LACMs, while China, India, Israel and North Korea either have development projects in progress or harbour an undeclared capability. As of late 2022, some 30 countries now have a conventional LACM in their inventory or on order.

Ballistic- and Cruise-missile Global Trajectories

While the 'big three' developers – China, Russia and the US – are considered elsewhere in this dossier, notable ballistic-missile developments continue in other parts of the world and in some cases are gathering pace. Accuracy and survivability continue to be foci for development, while hypersonic boost-glide-vehicle (HGV) and hypersonic cruise-missile (HCM) technology is also being independently and collaboratively pursued in Europe and the Indo-Pacific.

LACMs have a transparent military utility, and efforts to control their spread have been aimed notionally at curtailing their availability as delivery vehicles for weapons of mass destruction (WMD) rather than as a weapon technology per se. Attempts at constraining the acquisition or development of such systems, however, have at best only been partially successful. The United States' use of conventionally armed LACMs in the Gulf War simply primed demand, something that some producers were more willing than others to meet, which in turn fed further interest as the capability was introduced into regions.

The 1987 Missile Technology Control Regime (MTCR) was aimed mainly at minimising the spread of surface-to-surface ballistic missiles (SSMs) with performance parameters equal to or exceeding that of a 9K72 *Elbrus* (RS-SS-1C *Scud*-B): that is, a weapon able to deliver a

Key takeaways

UNEVEN PROLIFERATION

Ballistic and cruise missiles have proliferated at varying rates since the end of the Cold War. During the 1990s, many states retired and dismantled their ballistic-missile arsenals. That trend, however, has since reversed as many states regard ballistic missiles as useful conventional war-fighting tools.

CRUISE PROLIFERATION

Conventional land-attack cruise missiles have spread widely, having only been possessed by a handful of states in the early 1990s. Today, up to 30 states either possess LACMs in their inventory or have them on order.

BALLISTICS IN EUROPE

In Europe, conventional air-launched cruise missiles have proliferated widely, often as the result of collaborative programmes. A limited number of European states possess or are seeking to acquire ballistic missiles. Those that possess ballistic missiles generally operate them for potential nuclear missions.

MIDDLE EAST OPERATORS

Proliferation trends in the Middle East are comparatively more mixed, with multiple states acquiring or developing both ballistic and cruise missiles. Aside from Iran and Israel, much of this has been the result of procurement from foreign suppliers. This reliance will likely be reduced in the future, given multiple domestic development programmes.

ASIA-PACIFIC ARMS RACES

In the Asia-Pacific, there are multiple arms races ongoing between regional powers. However, due to different defence and deterrence requirements, competitors might not always choose to mirror the capabilities possessed by their adversaries.

500-kilogram payload to a range of 300 kilometres or more. The payload weight was drawn from the assessed weight of an earlier-generation nuclear warhead. The MTCR's seven original signatories have grown to 35, with the non-binding regime scoring notable success in curtailing the spread or development of 'ballistic' systems. Success regarding cruise-missile performance and uninhabited aerial vehicle (UAV) technology has been far more limited, in part because of how key enabling technologies have emerged in the years since the regime was drafted, in addition to the difficulties of amending restrictions to better address changes in capability. There has also been a greater moral or ethical acceptance of acquiring LACMs or UAVs when compared to ballistic missiles, due to the latter's historical association with biological, chemical and nuclear payloads.

Europe's Ballistic Capabilities

Europe's two nuclear-weapons states, France and the United Kingdom, both rely on nuclear-powered ballistic-missile submarines (SSBNs) for deterrence. In the UK's case, it is its only nuclear capability, while France's submarine force is supported by the Strategic Air Forces' inventory of air-launched supersonic nuclear-armed cruise missiles. Neither state currently possesses a ground-launched missile, although the UK has an ambition to procure a conventional system. Turkey is also noteworthy in the conventional realm, given its current arsenal and its level of ambition.

As stated, France's current ballistic-missile arsenal is sea-based, following the retirement of the ground-launched mobile *Pluton* SRBM and the silo-based S3D intermediate-range ballistic missile (IRBM) in 1996.[1] Both of these systems were armed with nuclear warheads. Justifying their retirement, French officials explained that these systems were no longer needed given the collapse of the Soviet Union and that their possession was incompatible with France's policy of 'strict sufficiency'.[2] The cost of maintaining, modernising and eventually replacing the S3D was also a significant factor in the French government's decision to withdraw it from service.[3]

Since the retirement of the *Pluton* and the S3D, France's ballistic-missile inventory has been centred around the M45 and variants of the successive M51 submarine-launched ballistic missiles (SLBMs). The three-stage, solid-fuelled M51 began to enter service in 2010 as a replacement for the M45, a process which is now complete.[4] France's SLBMs are equipped aboard four *Triomphant*-class SSBNs, each of which is equipped with 16 launch tubes. The M51 has been incrementally upgraded since it entered service, with the M51.2 variant now in service across the SSBN fleet.[5] While the M51.2 shares some components with the now-retired M45, including an identical solid-propellant, third-stage engine, the new missile has improved range, accuracy and penetrability over its predecessor, although French officials have stated it is less accurate than the *Trident* II D5, the SLBM operated by the UK and the US.[6] The M51's range has never been officially disclosed, but it is believed to be greater than 9,000 km.[7] The missile was initially equipped with six TN-75 multiple independently targetable re-entry vehicles (MIRVs) but, beginning in 2015, these have been replaced with the Tête nucléaire océanique (TNO) nuclear warhead.[8] While the M51.1 was known to be capable of carrying six TN-75 MIRVs, the number of TNO warheads that each SLBM can carry has not been disclosed. Although each TNO warhead is around twice the weight of the TN-75, it appears that aerospace company ArianeGroup – the M51's manufacturer – has compensated for this weight increase by ensuring that the M51.2 has a more powerful propellant than earlier iterations.[9] Work on the successive M51.3 began in 2014 and it is planned to enter service in 2025, further improving the missile's range and accuracy.[10]

France is also developing an HGV through a research project known as V-MaX (véhicule manœuvrant expérimental).[11] Few details about the system are currently known beyond an announcement by former defence minister Florence Parly that a test flight would take place in 2021.[12] Whether this took place is unknown, as is the intended warhead for the HGV. However, given that France lacks a suitable delivery vehicle for V-MaX beyond the M51 SLBM, it is likely the HGV will be submarine-launched. Statements from French officials emphasising the need for France 'to maintain and adapt our deterrent force and credibility', as well as private conversations through the Missile Dialogue Initiative, suggest that the V-MaX will have a nuclear-delivery role.[13]

Like France's, the UK's current ballistic-missile arsenal is centred around its sea-based nuclear forces following the retirement of the nuclear-armed MGM-52 *Lance* SRBM in 1993.[14] The UK's decision to scrap the *Lance* was made along with other broad cuts to the size and shape of the UK's nuclear deterrent following the collapse of the Soviet Union in 1991. The UK's ballistic-missile forces consist of 48 three-stage, solid-fuelled UGM-133 *Trident* II D5 LE SLBMs. These are carried aboard four *Vanguard*-class SSBNs, the delivery platform for the UK's nuclear deterrent. The D5 LE is an upgrade of the original D5 missile and is equipped with a new guidance system known as the MARK 6 MOD 1.[15] A second life-extension project known as *Trident* D5 LE2 commenced in 2020 and will keep UK (and US) SLBMs in service, aboard the successor *Vanguard*- and *Columbia*-class SSBNs respectively, until at least 2084. *Trident* has an estimated range of 12,000 km and can carry eight nuclear warheads. In 2020, the UK government announced that it would develop a replacement warhead for *Trident*, which will be available from the late 2030s.[16]

After three decades of only operating a strategic-range and nuclear-armed ballistic missile, the UK government announced in 2022 that it intends to procure the ground-launched Precision Strike Missile (PrSM)

TURKEY
Turkey's ballistic-missile programme is becoming more advanced.
CREDIT: Eko Siswono Toyudho/Anadolu Agency/Getty Images

from the US.[17] PrSM is a single-stage, solid-fuelled SRBM under development by Lockheed Martin that is expected to enter service in the US by 2023.[18] The missile has a range of 499 km. Up to four PrSMs can be launched from the M270A2 multiple-launch rocket systems (MLRSs) or two rounds from the lighter and smaller High Mobility Artillery Rocket Systems (HIMARSs). In anticipation of this procurement, the UK is upgrading its fleet of 44 M270B1 MLRSs to the M270A2.[19] The British Army is also creating a new formation, the 1st Deep Recce Strike Brigade Combat Team, to direct and utilise its planned ground-launched missile capability.[20] This procurement decision reflects a recognition and concern among UK policymakers that the British Army lacks the organic capability to launch long-range strikes compared to its adversaries' ground forces, especially those of Russia.[21]

Turkey currently possesses several types of foreign and indigenously developed SRBMs, but the country's leadership has stated it has ambitions to develop much longer-range systems.[22] While claims by some Turkish defence officials that designing a 2,500-km-range system is 'a realistic target' may have seemed unachievable when first suggested a decade ago, the advancement of Turkey's indigenous missile programme and its efforts to achieve defence-industrial autonomy suggest that Turkey will be able to partly realise these ambitions in the future.[23] Turkish analysts have suggested, however, that developing a ballistic missile with a 2,500-km range would not align with Turkey's immediate defence requirements, with an optimum range of around 800 km being more appropriate and achievable.[24]

Turkey's domestic ballistic-missile programme has been led by the Turkish weapons manufacturer Roketsan, which has worked closely with Chinese manufactures, especially China Precision Machinery Import–Export Corporation (CPMIEC).[25] Through technology transfers with China, Turkey has accelerated its indigenous ballistic-missile programme, resulting in the production of several designs that are based on Chinese technology, including the *Kasırga* and *Kaplan* MLRSs, which are derivatives of the Chinese WS-1 rocket, and the *Yıldırım* and *Bora* SRBMs, which are adaptations of China's B-6-11 (CH-SS-9 mod 1) and B611M SRBMs respectively.[26] Turkey's armed forces possess at least four *Yıldırım* and an unknown number of *Bora* launchers.[27] *Bora* is an upgraded variant of *Yıldırım* and extends the missile's range from 150 to 280 km.[28] The incorporation of a GPS/INS guidance package also has reduced the missile's circular error probable (CEP) from roughly 150 metres to around 10 m.[29] Ankara also purchased 72 MGM-140A Army Tactical Missile Systems (ATACMSs) from the US in 1996, reportedly as a precondition for Turkey to join the MTCR.[30] More recently, Turkey appears to be making progress on achieving its ambition of increasing the range of its domestically produced ballistic missiles, having tested an SRBM (known as *Tayfun*) with an estimated range of 560 km in October 2022.[31] *Tayfun*'s ultimate planned range and the number of launchers that the Turkish Armed Forces seek to possess are unknown, as the missile is still in development. However, the apparent success of *Tayfun*'s development marks an advancement in Turkey's domestic missile-production capabilities.

There has not been an official explanation for why Turkey is pursuing increasingly longer-range systems, although Turkish Prime Minister Recep Tayyip Erdoğan has said that the threat posed by the increasing range of Iran's arsenal has driven this aspiration.[32] Armenia's and Greece's possession of ballistic missiles with ranges comparable to Turkey's current inventory may also be a factor, as having an enhanced capability to launch strikes from beyond the range of potential counter-fire would be appealing to the Turkish Armed Forces.[33]

LACMs: European Early Adopters

During the 1980s several NATO member states had considered the collaborative acquisition of a conventional air-launched cruise missile (ALCM) as part of the Modular Stand-Off Weapon (MSOW) project.[34] These included Canada, France, Italy, Spain, West Germany, the UK and the US. The programme fragmented and eventually fell apart in 1989 over differing requirements, priorities and concerns around technology transfer.[35] The MSOW B variant was meant to provide an LACM with a range of 600 km, which could be used to engage fixed targets as part of the Alliance's AirLand Battle doctrine and could counter the capabilities of the Warsaw Pact members. One concern among the non-US partners was that Washington was also pursuing then-classified national developments to meet a similar requirement. Following the collapse of the MSOW project the US released limited information on the low-observable Northrop AGM/MGM-137 Tri-Service Standoff Attack Missile (TSSAM), the air-launched variant of which was to have a range of 600 km. This programme, however, met a similar end to that of the MSOW, being cancelled in 1994 because of development problems and spiralling costs.[36]

During the same period the US introduced conventionally armed variants of cruise missiles, originally designed for nuclear-delivery roles, into service. While NATO collaborative programmes failed to reach fruition, the United States' use of both types during the Gulf War only served to highlight this class of weapon's worth within America's inventory. Although the MTCR might hamper some countries' acquisition ambitions, it would not stymie them altogether.

All the non-US MSOW partners, barring Canada, would, however, continue to pursue the acquisition of an air-launched LACM, eventually either by an off-the-shelf purchase or through a national development programme. London's participation in the MSOW was intended to meet Staff Target (Air) 1236, which identified the need for a stand-off missile to be used against hardened targets such as aircraft shelters or command-and-control nodes. By 1995, Staff Requirement (Air) 1236 had resulted in the UK's Ministry of Defence releasing an invitation to tender for the Conventionally Armed Stand-Off Missile (CASOM) programme.[37] The *Storm Shadow* proposal from BAe Dynamics and Matra Defense was selected in July 1996 to meet the requirement. While neither the Ministry of Defence nor the developer, MBDA, has released actual range figures for the UK *Storm Shadow* beyond noting the weapon had a range above 250 km, the 600-km-range goal of the MSOW was met.

The selection of the BAe Dynamics and Matra Defense proposal also provided the basis for the merger of the two guided-weapons manufacturers to form Matra BAe Dynamics.[38] Known now as MBDA, the company has also absorbed other guided-weapons businesses from France, Germany and Italy. France bought the missile, where it was known as SCALP EG (Système de Croisière Autonome à Longue Portée – Emploi Général). Variants of the *Storm Shadow*/SCALP EG were sold within Europe to Italy and Greece, as well as further afield to the Middle East (these latter exports will be addressed later in this chapter).[39] Germany also entered the CASOM competition with the LFK/Bofors *Taurus*/KEPD-350. Although unsuccessful in the UK, the weapon was purchased by the German and Spanish air forces.[40] Like *Storm Shadow*, it has also been sold outside of Europe, but in this case to the Asia-Pacific.[41]

Storm Shadow, however, was not the UK's first long-range conventionally armed LACM. In 1995 the UK government ordered the Raytheon UGM-109C *Tomahawk* submarine-launched LACM.[42] It was, however, only ordered in a fraction of the numbers of *Storm Shadow*. London initially ordered 65 of the weapons, with subsequent small top-up orders when the UK's stockpile needed replenishing. In

EUROPEAN COLLABORATION
The *Storm Shadow*/*SCALP*-EG LACM, developed jointly by France and the UK, is displayed at the Dubai Airshow, 20 November 2005. CREDIT: Rabih Moghrabi/AFP/Getty Images

TURKISH CRUISE MISSILES
The SOM cruise missile is exhibited at the SAHA EXPO Defence & Aerospace Exhibition, 28 October 2022. The SOM is part of Turkey's larger ambitions to develop greater air- and sea-launched cruise-missile capabilities. CREDIT: Muhammed Enes Yildirim/Anadolu Agency/Getty Images

contrast, an estimated 900 *Storm Shadows* were bought for the Royal Air Force.[43] The French Navy followed the UK in 2000 with the requirement for a surface ship and submarine-launched LACM. Initially called SCALP Naval, it was later referred to as the MdCN (Missile de Croisière Naval) and then as a Naval Cruise Missile.

To date, the UK is the only operator of the *Tomahawk* outside the US, although at various points other US allies, including Israel, have raised the possibility of acquisition.[44] Washington, however, has maintained a conservative approach to exporting this class of missile and its associated targeting system, in no small part due to the MTCR. The United States' constraint on the sale of *Tomahawk*, however, has begun to slacken, as Washington will likely sell the missile to Canberra as part of the Australia, UK, US (AUKUS) trilateral military accord.[45]

The UK and France are now working on a successor capability to the *Storm Shadow*/SCALP EG under the banner of the Future Cruise/Anti-Ship Weapon (FCASW). The concept and assessment phase of the programme began in 2017.[46] The programme is being developed around two designs: a low-observable subsonic cruise missile to replace *Storm Shadow*/SCALP EG from around 2030 and an anti-ship missile with performance in the high-supersonic range. France is the only European nation to presently field a supersonic LACM, the nuclear-armed, ramjet-powered ASMPA (Air-Sol Moyenne Portée Amélioré). It is now working on a successor, the ASN4G (Air-Sol Nucléaire 4ème Génération), which is intended to fly in the hypersonic flight regime at a speed of greater than Mach 5. Study work on the ASN4G was under way by 2014, with Paris intending for the missile to enter service from 2035.[47] The UK also has renewed its interest in hypersonic cruise missiles after cancelling several high-speed projects in the early 2000s, in part with its involvement in the AUKUS security pact.[48]

There are a further two European producers of LACMs, though these have so far been in a lighter category than that of *Storm Shadow* or KEPD-350. Norway's Kongsberg began work on the Naval Strike Missile (NSM) in 1996, which, whilst its primary role was anti-ship, had a secondary land-attack capability.[49] In 2005 Kongsberg began to promote the NSM as the basis for an air-launched LACM suitable for internal carriage on the Lockheed Martin F-35A *Lightning* II. The Norwegian Ministry of Defence allocated initial development funding for what was to be known as the Joint Strike Missile (JSM) in 2009, with a series-production contract awarded in 2021.[50] The missile will be in operational service with the Royal Norwegian Air Force in 2025.

The F-35 carriage also drove the design of the Turkish SOM-J LACM, which was sized to fit in the main weapon bay of the aircraft.[51] Derived from the slightly larger original SOM design, whether the missile will now ever feature on an F-35 is now unclear, given Ankara's exclusion from the programme. While the SOM-C2 variant of the missile weighs 635 kg, Turkey also has a far larger LACM in development. The *Gezgin* is a 1,300-kg-class LACM intended for naval vessels, while a ground-launched cruise missile (GLCM) variant has also been suggested.[52] Turkish interest in a naval LACM reportedly was kindled in the early years of the twenty-first century, but it had neither the access to purchase this class of weapon nor the national technology base to pursue its domestic development.[53] The revived project has been running now for just under ten years, with an introduction into service intended sometime in the second half of this decade. There remains a question, however, as to the propulsion system for the missile. The SOM family was originally powered by the French Safran TR40 turbojet, and Ankara had also relied on France as the initial engine provider for *Gezgin*. Relationships, however, appear to have broken down, perhaps in part because of export issues concerning SOM. Instead, Turkey looked to Ukraine to provide the engine for the LACM, with a variant of the Ivchenko-Progress AI-35.[54] A small initial batch of engines may have been delivered. The extent to which this programme will be affected by Russia's invasion of Ukraine remains to be seen. Turkey, assuming *Gezgin* is successfully developed, would become only the second European country to domestically produce a long-range naval LACM after France.

While the UK is the only operator of the US *Tomahawk*, US air-launched LACMs

***ISKANDER*-E SRBM**
Armenia has recently purchased the *Iskander*-E SRBM from Russia. CREDIT: Contributor/Getty Images

have been acquired more broadly in Europe. Finland, the Netherlands and Poland have purchased the Lockheed Martin AGM-158 Joint Air-to-Surface Standoff Missiles (JASSM), a weapon similar in class to the *Storm Shadow*/SCALP EG.[55]

Ballistic Use in Eurasia

The short war in 2020 between Armenia and Azerbaijan likely included the launch of CRBMs or SRBMs, though reporting and claims remain contradictory and unclear. Armenia possesses a mixture of legacy Soviet and modern Russian SRBMs including at least seven 9K72 *Elbrus* (RS-SS-1C *Scud*-B), three 9K79 *Tochka* (RS-SS-21 *Scarab*) and four 9K720 *Iskander*-E (RS-SS-26 *Stone*) SRBMs.[56] The *Iskander*-E is a shorter-range export version of Russia's *Iskander* SRBM that is limited to 280 km to comply with export restrictions of the MTCR. Former Armenian president Serzh Sargsyan pointed to tensions with neighbouring Azerbaijan and Baku's procurement of precision-strike capabilities as driving Yerevan's procurement decision.[57]

Despite Armenia's possession of a precision-strike system that could be used to target military and critical national infrastructure in parts of neighbouring Azerbaijan, there are conflicting accounts as to whether the Armenian Army used *Iskander* during the 2020 Nagorno-Karabakh war. Multiple former Armenian civilian and defence officials have claimed that *Iskander* was used on several occasions toward the end of the conflict, although Russia and Azerbaijan deny this.[58] However, wreckage of a missile casing recovered in Azerbaijan matching the design of *Iskander*, in addition to footage of what appears to be an *Iskander* launch, arguably support Armenia's claim.[59]

Following the 44-day war with Azerbaijan, the Armenian government laid out its armed forces' priorities, including 'the processes of modernising armament and military equipment and acquiring new samples'.[60] While the details of Yerevan's modernisation plans are not known, given its possession of several types of legacy ballistic missiles, it might wish to replace its older equipment with more modern systems. However, Armenia's traditional supplier of arms – Russia – may not now have spare capacity to assist this programme given its own equipment requirements arising from losses sustained in Ukraine. Armenia may therefore look to alternative potential suppliers further afield.[61]

Like Armenia, Azerbaijan retains a mixture of legacy Soviet ballistic missiles as well as more modern equipment that has been procured as part of Azerbaijan's defence-modernisation and -procurement programme. There is significant procurement and defence cooperation between Azerbaijan and several regional partners – especially Israel and Turkey – regarding guided weapons.[62]

Azerbaijan's ballistic-missile arsenal consists of an estimated four 9K79 *Tochka* launchers and two Long Range Artillery (LORA) launchers manufactured by Israeli firm IAI.[63] LORA is a single-stage, solid-fuelled SRBM that flies on a quasi-ballistic trajectory to a range of 280 km. It is equipped with a 600-kg warhead and is guided by GNSS- and INS-enabling precision strikes. Each launcher is equipped with four missile canisters allowing for multiple launches.[64] It is likely that Azeri forces used LORA during the 2020 Nagorno-Karabakh war, as footage of a missile strike on a small bridge indicates the use of a precision-strike system that is beyond the capabilities of the less accurate *Tochka*.[65]

Although Israel has so far been the only supplier of ballistic missiles to Azerbaijan, Turkey's increasingly advanced domestic missile-production capabilities and Ankara's close relationship with Baku may provide Azerbaijan with additional opportunities to improve its missile forces qualitatively and quantitatively through additional foreign procurement.

Ballistic Trajectories in the Middle East

At least eight countries in the Middle East and North Africa count ballistic missiles within their inventory: Algeria, Bahrain, Egypt, Iran, Israel, Qatar, Saudi Arabia and the United Arab Emirates (UAE). Israel's inventory is key to its still-undeclared nuclear capability, while the others retain a variety of CRBMs, SRBMs and medium-range ballistic missiles (MRBMs). While Syria and Yemen have historically possessed large ballistic arsenals, the service status of these systems is unclear due to the respective ongoing civil wars. The region has also seen the proliferation and use of ballistic missiles by Ansarullah and Hizbullah, with Tehran being the source of these weapons.

Egypt's missile arsenal is limited but of interest due to Cairo's historic and long-standing aspirations to develop missile technology, as well as its history of pursuing WMD. The Egyptian Armed Forces' initial interest in acquiring ballistic missiles was partly driven by concerns that it lacked a sufficient air capability to strike targets in neighbouring Israel.[66] Initially unable to acquire Soviet missile technology, Cairo instead embarked on a domestic programme that was partially based on repurposing German V-2 designs from the Second World War.[67] This resulted in the testing and operational fielding of several indigenous liquid-fuelled designs, including the *Al Zafir* and *Al Kahir* in the 1960s.[68] The utility of these systems was questionable, however, as both missiles were reportedly very inaccurate due to unresolved guidance issues.[69] The Soviet Union's long-standing refusal to supply Egypt with ballistic missiles was eventually reversed after Cairo expelled Soviet advisers in 1972, with the first Soviet-designed *Scud*-B missiles arriving in Egypt in 1973.[70] Despite the transfer, Egypt's ballistic-missile arsenal remained under Soviet control, and the limited use of the weapons against Israel in the 1973 Yom Kippur War was mostly a political gesture demonstrating Egypt had the capability to attack Israeli cities.[71]

Egypt's rapprochement with the US following the 1979 Egypt–Israel peace treaty terminated potential further Soviet missile deliveries to Egypt, and Cairo resultantly refocused its efforts to produce an indigenous ballistic-missile design. One partially realised output of this effort was the *Condor* II project, a trilateral development between Argentina, Egypt and Iraq to illicitly finance, design, test and deploy a solid-fuelled ballistic missile with a range of 750–1,000 km.[72] International pressure led by the US and coordinated through the MTCR, however, forced Argentina – the missile's main developer – to terminate the project in 1991.[73] Egypt appears to have continued with the project in some form – retitled *Project Vector* – until the early 2000s.[74] The programme's current status is unknown. The expansion of a possible ballistic-missile testing facility known as the Jabal Hamzi Surface-to-Surface Missile Complex between 2000 and 2010 suggests that Egypt may be continuing to refine some of its older Soviet-supplied technologies.[75] The IISS estimates that Egypt possesses nine *Scud*-B launchers.[76]

Iran possesses the largest and most varied ballistic-missile arsenal in the Middle East. Its missile forces form a central part of Iran's deterrence architecture, a strategy which is endorsed by Iran's supreme leader Sayyid Ali Khamenei.[77] Iran also relies heavily on missiles to offset its qualitative inferiority in military equipment in the land, sea and air domains compared with its regional rivals. Long-standing but now-lifted export controls had prevented Iran from modernising its existing equipment or placing new orders with friendly countries, such as Russia. With the ban now lifted, Tehran has agreed to sell ballistic missiles, as well as UAVs, to Moscow.[78]

Iran possesses an estimated 20 different types of solid- and liquid-fuelled ballistic missiles, all of which have ranges at or below 2,000 km to comply with a voluntary limit reportedly attributed to Iran's supreme leader.[79] However, some Iranian systems, such as the *Khorramshahr*, are capable of travelling beyond this range if the missile's warhead weight is reduced.[80] Iran's ballistic-missile programme has surprising origins, having begun as a cooperative effort with Israel from 1977–79.[81] However, the Iranian Revolution and the subsequent diplomatic fallout resulting in Iran's international isolation restricted the possibility of further technology transfers. Iraq's use of ballistic missiles against Iranian cities during the Iran–Iraq War, however, put significant pressure on Iran's leaders to respond in kind given that Iran lacked

KHEIBAR SHEKAN
Iran has the largest ballistic-missile arsenal in the Middle East, which includes the *Kheibar Shekan* MRBM. CREDIT: Contributor/AFP/Getty Images

a ground-launched missile capability.[82] Collaboration with Libya and technology transfers with North Korea provided Iran with its first ballistic missiles in the form of the Soviet-designed *Scud*-B. Transfers to Iran also laid the foundations of a domestic production capability by initially adopting North Korean derivatives of Soviet technology. For instance, the Iranian *Shahab*-3 is a copy of the North Korean *Hwasong*-7, which itself is a copy of the *Scud*-B. Despite arms embargoes placed on Iran and North Korea, both countries have continued cooperating on illicitly transferring critical missile technology to the present day.[83] This continued cooperation is evident through the technological lineage of some Iranian missiles, such as the *Khorramshahr* MRBM, a derivative of the North Korean *Musudan*, which itself is a spin-off of the Soviet R-27 Zyb (RS- SS-N-6 *Serb*), a single-stage, liquid-fuelled SLBM.[84]

Despite Iran's earlier reliance on foreign technical assistance and technology, it has made significant efforts to build its domestic missile-production capability. Although some of Iran's early indigenous designs, such as the *Shahab*-1, suffered from poor accuracy and long launch-preparation times, Iran has persistently improved the utility of its ballistic-missile arsenal through illicit missile-technology acquisition.[85] As a result, Iran has been able to retroactively improve its older missiles as well as design more advanced systems. As an example of the former, the single-stage, liquid-fuelled *Ghadr*-1 is a variant of the *Shahab*-3 but benefits from a lighter and stronger airframe and a reshaped nose cone that improves the impact velocity of the warhead.[86] Regarding newer systems, Iran's single-stage, solid-fuelled *Zolfaghar* has been used by Iranian forces on several occasions against targets in Syria and Iraq and has displayed a very high level of accuracy due to incorporation of GNSS guidance packages.[87] The improvement of Iran's missile forces reflects Tehran's changing priorities and missile doctrine from a focus on punishment and deterrence, as conceived from Iran's experience in the Iran–Iraq War, to one of denying Iranian adversaries their military objectives by using much more accurate missiles that are capable of being used for precision-strike missions.

Israel's ballistic-missile arsenal is tasked with providing strategic deterrence as well equipping the Israeli Defense Forces (IDF) with conventional options through a dedicated conventional SRBM. As Israel does not officially acknowledge that it possesses nuclear weapons, public information on its associated ballistic-missile programme is limited.

Israel's early defence-industrial base for ballistic-missile production was galvanised by cooperation with France, particularly the aeronautics firm Dassault.[88] Israel's pre-emptive military actions in the 1967 Six-Day War abruptly ended this relationship, however, necessitating greater indigenous development.[89] The single-stage, solid-fuelled and road-mobile *Jericho*

SRBM was Israel's first ballistic missile and was in service from approximately 1973–90. The missile had a range of around 500 km, thus placing large population centres in Egypt, Jordan, Lebanon and Syria within range.[90] The subsequent two-stage, solid-fuelled *Jericho* II is a longer-range system, the development of which appears to have begun in the mid-1980s, with initial operational capability (IOC) being reached by 1994.[91] While the missile's parameters are unknown, analysis of the related *Shavit* space-launch vehicle indicates that at least the first stage is solid-fuelled and that the missile has a range of around 2,000 km.[92] The IISS estimates that Israel possesses roughly 24 of these systems.[93] Israel reportedly also has developed a longer-range system, a three-stage, solid-fuelled IRBM known as the *Jericho* III. Although the system's range is unknown, analysts have suggested that it may have been developed to provide greater coverage over Iran, a capability which the shorter-range *Jericho* II lacked.[94] Whether the *Jericho* III and II are operated concurrently is unknown, but it is likely that Israel will retire its older system in favour of the *Jericho* III in the future. Israel is also thought to operate the single-stage, solid-fuelled and conventionally armed LORA SRBM which it has exported to Azerbaijan, although inter-service rivalry within the IDF appears to have slowed acquisition plans.[95]

Iran and Israel are not the only possessors of medium-range systems in the Middle East. The Royal Saudi Strategic Missile Force's (RSSMF) force structure and planned future capabilities have been shrouded in obscurity since Riyadh first procured ballistic missiles from China in 1988. Saudi Arabia possesses at least two MRBMs, both of which it procured from China: the DF-3A (CH-SS-2) and the DF-21 (CH-SS-5). There have been suggestions by analysts that Saudi Arabia may possess an unknown third type of ballistic missile.[96] Riyadh also appears to be devoting significant resources to developing a ballistic-missile production facility, also apparently with Chinese assistance.[97]

The DF-3A (CH-SS-2) is a one-stage, liquid-fuelled MRBM that can carry a 2,000-kg payload to an estimated range of around 2,500 km. The number of systems Saudi Arabia purchased from China is unclear, but the US Department of Defense reports that the RSSMF's inventory is fewer than 50.[98] Beyond two missiles being displayed at a 2014 parade, the system's service status is unclear, given their age, difficulties of maintenance, a lack of spare parts and likely general deterioration.[99] The DF-3A's estimated CEP of 1,000–4,000 m precludes it from striking anything except for very large targets and its military utility as a conventional weapon is therefore limited. Despite this, Saudi Arabia's decision to purchase the system may have been driven by its need to possess a deterrent amid regional instability and uncertainty in the 1980s, especially vis-à-vis Riyadh's concerns about Iran and Israel.[100] Statements by Saudi Arabia's leadership from the time appear to suggest that Saudi Arabia viewed these systems as a means of deterrence of its neighbours.[101]

Riyadh's decision to purchase Chinese missiles was likely driven by Washington's refusal to supply Saudi Arabia with alternatives, such as the shorter-range MGM-52 *Lance*, which the Saudi government requested from the US in 1979.[102] Despite the diplomatic fallout with the US that resulted from the purchase of the DF-3A, Saudi Arabia and China continued to transfer ballistic-missile technology.[103] Likely seeking to upgrade its deterrent, Saudi Arabia purchased the DF-21 MRBM from China in 2007.[104] While the DF-21 has a shorter range than the DF-3A, its use of solid fuel shortens launch preparation time and its greater level of precision means it can be used for more accurate strikes. Despite US displeasure over Saudi Arabia's procurement of the DF-21, reporting states that Washington approved the sale once Riyadh allowed US technical experts to inspect the DF-21 and verify it was unable to carry a nuclear warhead, a request which the Saudis had rejected in the 1980s when purchasing the DF-3A.[105]

Chinese–Saudi cooperation has extended beyond the sale of equipment. Imagery analysis of a site near al-Watah shows evidence of an engine-production and -test facility which appears Chinese in design.[106] US officials later confirmed that Saudi Arabia had commenced the production of solid propellant at the site.[107] What missile Saudi Arabia is manufacturing is unknown, although analysts have suggested it could be a Ukrainian-designed system known as *Grom*-2, the development of which Riyadh is believed to be funding.[108] Whatever the missile, it appears that it will be a solid-fuelled design, based on the presence of a burn pit near the engine test stand that is used to dispose of leftover

***SHAVIT* SLV**
Israel's ballistic-missile and space-launch-vehicle programmes, including the *Shavit* SLV, are believed to be closely connected.
CREDIT: Pallava Bagla/Corbis News/Getty Images

HIMARS LAUNCHER
The UAE operates 12 HIMARS launchers which can fire the ATACMS SRBM. CREDIT: Giuseppe Cacace/AFP/Getty Images

propellant.[109] Riyadh's decision to move to domestic production is likely driven by its desire to acquire a larger and possibly more capable deterrent, given that its arch-rival, Iran, possesses the largest ballistic-missile arsenal in the Middle East. Reducing its reliance on foreign partners and the potential ramifications of these transfers – especially with the US – is a possible secondary factor for Riyadh. The United States' response to this development has been muted, and Saudi Arabia's decision to pursue the domestic production of ballistic missiles will likely further complicate any attempt to constrain Iran's ballistic-missile arsenal through diplomatic means, as Iran will likely object to having its missile arsenal singled out.

The UAE's ballistic-missile arsenal consists of a small number of SRBMs procured from divergent sources. In 1999, the UAE received a shipment of roughly 30 R-17 *Elbrus* (SS-1C *Scud*-B) and SS-1D *Scud*-C SRBMs from North Korea.[110] The IISS estimates that the UAE possesses six launchers for these SRBMs and that its stockpile of missiles is now fewer than 20 units, as maintaining these missiles will be difficult over time.[111] Neither system is particularly accurate, which, along with long launch-preparation times, means they are of little military value.

Of greater utility are the UAE's M57 ATACMS T2K (Block IA Unitary) SRBMs. The UAE has procured 100 Block 1A missiles from the US, along with 12 HIMARS launchers in 2014.[112] The M57 ATACMS Block IA (Unitary) can deliver a roughly 225-kg warhead to a range of 70–300 km. It is fitted with INS and GPS guidance, allowing for the missile to strike individual targets with a high degree of accuracy. HIMARS's utility is amplified as it can also launch surface-to-surface rockets from the M270 family of launcher weapons platforms, such as the M31A1 Guided Multiple Launch Rocket System (GMLRS) Unitary, which the UAE possesses.[113] The GMLRS is armed with a roughly 90-kg high-explosive warhead and is GPS and IMU guided for precision strikes against soft and hardened targets at ranges up to 70 km.[114] It appears that the UAE deployed some HIMARS systems to Yemen in 2015.[115]

Other states in the Gulf Cooperation Council have also procured ballistic missiles from foreign sources, although these systems have shorter ranges. Algeria, like Armenia, also operates the *Iskander*-E SRBM, of which Algeria received 12 from Russia in 2018.[116] Bahrain operates nine M270 MLRSs which can be used to launch the MGM-140A ATACAMS, 30 of which the Bahraini government purchased from the US in 2000.[117] The MGM-140A is a single-stage, solid-fuelled missile that is capable of dispersing 950 M74 bomblets to a range of 165 km.[118] Bahrain later procured another version of the ATACMS known as M57 T2K Unitary from the US in 2018.[119] The M57 is a single-stage, solid-fuelled SRBM that can strike targets up to 270 km away with a 227-kg high-explosive warhead.[120] Qatar possesses at least eight Chinese-designed BP-12A (CH-SS-14 mod 2) SRBMs, which it publicly displayed in 2021.[121] It is likely Qatar purchased these systems from China after requests from Doha to Washington to procure the MGM-140 ATACMS failed to produce results.[122]

The Middle East and Ballistic Reactions

If, understandably, the regional focus has been on the acquisition and/or development of SSMs, LACMs also have become increasingly present. The region also has the unwelcome distinction of seeing the first use of an LACM by a non-state actor (NSA), Ansarullah. As yet, only two countries in the region have domestically developed long-range LACMs, while several others have instead purchased air-launched weapons in this class from partners outside the region.

Israel was probably the first country in the region to introduce both long-range submarine-launched and air-launched LACMs into its inventory. It has, however, yet to publicly show either capability. This may be because the submarine-launched weapon, and perhaps also the air-launched missile, may have both conventional and nuclear-armed variants. The *Dolphin*/*Tanin*-class submarine reportedly has the capacity to be equipped with an LACM, whilst a version of the Rafael *Popeye* 2 air-to-surface missile fitted with a turbojet engine was in development in the latter part of the 1990s.[123] In the late 1990s Israel also expressed interest in the UGM-109 *Tomahawk*, but the US was unwilling to provide the weapon.[124] The country has also carried out experimental research with ramjet propulsion for missile applications. Algeria is the other regional country with a submarine-launched LACM, having purchased the *Novator* 3M14E (RS-SS-30B *Sagaris*) from Russia.

The other country with a domestic design and manufacturing capacity is Iran. Its inventory of LACMs can be viewed in part as a complement to its extensive stock of SSMs. Tehran's development of cruise missiles was built on experience and technology gained through the acquisition and production of anti-ship missiles. As with Turkey, Iran also looked initially to externally acquire suitable propulsion for its weapons. Its *Tolu* 4 turbojet resembles the French TRI-60, while more recently the Czech PBS Velka Bites TJ100 was used as the basis for a domestic engine.[125]

Iran's long-range LACM ambition was made clear in 2005, when Ukraine admitted that six *Raduga* Kh-55 (RS-AS-15 *Kent*) 2,500-km-range cruise missiles had been illicitly delivered to Tehran in 2001.[126] Six of the same nuclear-capable missiles had been provided to China in 2000.[127] The Kh-55 design led to a variety of Iranian developments, though the service status of them all remains in question. In 2012, Iranian officials identified a programme dubbed *Meshkat* that was intended to develop a 2,000-km-range LACM. Three years later, Iran announced that the *Soumar* LACM was in production; the missile was externally identical to the Kh-55. Then, in 2019, it showed the *Hoveyzeh*; again, the airframe design was that of the Kh-55. The engine housing, however, differed in that it appeared suited to a turbojet rather than a turbofan, and the range was given as 1,350 km.[128] While Tehran has often showed stores of ballistic missiles, anti-ship missiles and UAVs, no similar footage of LACM storage has ever been released, barring images of six Kh-55 lookalikes, the same number of missiles acquired from Ukraine. The reason for Tehran's secrecy in displaying any of its LACM inventory is unknown, but ambiguity around service-status uncertainties may be one explanation.

The shift from a turbofan to a less fuel-efficient turbojet suggests problems in developing the former. The choice of propulsion for what would appear to be another more successful LACM development programme also supports this notion. The 351/*Quds* has never been displayed by Tehran, but two variants of this LACM have entered production. The *Quds*-1 is a 700-km-range missile that was fitted with an unlicensed copy of the TJ100, while the *Quds*-2 provided a range extension to nearly 1,000 km. Both versions of the LACM have been supplied by Tehran to Ansarullah in Yemen, with the LACM being used for attacks on Saudi Arabia and the UAE. The *Quds* family so far has lacked any indication of terminal guidance, instead relying on an inertial system combined with GNSS. As such, it is not suitable for attacking targets where there is a requirement for high accuracy but it can be used against area targets such as the 2019 attacks on Saudi oil installations. A further cruise missile, similar in performance terms to the 351, known as *Ya-Ali*, was shown in 2014, but very little of this project has been seen since then and it may have fallen into abeyance. While all of Iran's LACM programmes have so far been surface-launched, a 351-sized missile would be suitable for air launch from some of Iran's inventory of military aircraft.

***DOLPHIN*-CLASS SUBMARINE**
The Israeli *Dolphin*-class submarine is believed to be equipped with a sea-launched cruise-missile capability. CREDIT: Gali Tibbon/AFP/Getty Images

Five other regional states have already acquired air-launched LACMs, either from Europe, the US, or in some cases both. The European MBDA *Storm Shadow*/SCALP LACM has been purchased by Egypt, Kuwait, Qatar, Saudi Arabia and the UAE; the last three as part of combat-aircraft packages, in the case of Egypt with the Dassault *Rafale*; with the other two, the Eurofighter *Typhoon*; and in the case of Qatar, also the *Rafale*. While all these countries operate US combat aircraft in their inventories, the Storm Shadow/SCALP EG/*Storm Shadow* is not integrated on any of these aircraft because of stipulations from Washington.[129], The sale of the *Black Shaheen* to the UAE was opposed by the US, citing the MTCR, as was the sale of the weapon to Saudi Arabia.[130] Riyadh's initial requests for a US LACM, the Boeing AGM-84H SLAM ER, were initially turned down around 2009, before a contract was eventually signed in 2020.[131] The UAE also likely has received the AGM-84H.[132]

The UAE is also now pursuing the domestic development of LACMs. The Abu Dhabi-headquartered Edge Group is developing a portfolio of guided weapons, and in 2021 it showed its *Saber* concept.[133] This is a 1,200-kg LACM design, with an advertised range of 290 km, conveniently just below the 300-km MTCR threshold.[134] For such a large missile, the stated 200-kg payload (warhead) also appeared small. By comparison, the 1,400-kg KEPD-350 has a 450-kg warhead. Edge has benefitted from South African guided-weapons expertise, with many former Denel Dynamics personnel now working for the company.[135]

While neighbouring Saudi Arabia has yet to show the same level of ambition as the UAE regarding a domestic LACM, some of the building blocks are under development. The King Abdulaziz City for Science and Technology is working on a turbofan engine, the TFK-500, which would be suitable for a large LACM.[136]

Indo-Pacific Ballistic Pressure

Regional tensions and rivalries have proved fertile ground for ballistic-missile programmes, both conventional and nuclear. Ballistic missiles are central for India, Pakistan and North Korea: Pakistan is developing a nuclear triad and India has the capacity to do so, as could North Korea. Japan, while not fielding any ballistic missiles, has indicated the goal of developing a ground-launched HGV that would require a solid-propellant booster.

India's ballistic-missile inventory is undergoing a gradual modernisation process as part of New Delhi's apparent shift toward viewing China rather than Pakistan as the nation's greatest security threat.[137] This recalibration has resulted in India's development of new types of ground- and sea-launched systems with increasingly longer ranges. Considering these, the high proportion of successful launches compared with older Indian systems suggests that the design capabilities of India's Defence Research and Development Organisation (DRDO) have steadily advanced. The modernisation of India's ballistic-missile forces also incorporates technological improvements that will improve the operational utility of these systems, such as transitioning from liquid-fuelled to solid-fuelled systems and increasing accuracy. Some analysts have suggested that these efforts are an attempt by India to develop counterforce capabilities.[138] While India operates a so-called 'force-in-being' policy wherein its nuclear-armed ballistic missiles are de-mated from their warheads, its development of sealed, canisterised ground-launched systems and SLBMs has raised concerns amongst analysts that its posture might evolve alongside developments in its modernisation programme.[139] Moreover, although Indian officials have reiterated India's continued adherence to a no-first-use policy, some analysts have argued that revisions to India's declaratory doctrine and statements

SOVIET ORIGINS
Iran's *Hoveizeh* LACM is exhibited in Tehran, February 2022. Iran's LACM arsenal is derived from the Soviet *Raduga* Kh-55. CREDIT: Atta Kenare/AFP/Getty Images

EDGE
The UAE is making investments in missile technology to become more self-sufficient. CREDIT: Christopher Pike/Bloomberg/Getty Images

by some Indian officials questioning its rationality have partially watered down New Delhi's commitment to this policy.[140]

India currently operates several types of shorter-range systems, including an estimated 12 *Agni*-I and 42 *Prithvi*-II SRBM launchers that are capable of ranges of 700 and 350 km respectively.[141] Due to their short ranges, both systems have limited utility against China and are instead likely focused on targeting Pakistan. Both systems are dual-capable, meaning they can be fitted with either conventional or nuclear warheads.

At longer ranges (e.g., for targeting China), India possesses around eight solid-fuelled, rail- and road-mobile *Agni*-II MRBMs which have an estimated range of up to 3,000 km.[142] The missile is claimed to have a small CEP due to the presence of inertial and GNSS navigation systems for guidance in the mid-course phase and a warhead with control surfaces for course correction in the terminal phase of flight.[143] The Indian Ministry of Defence claimed that the *Agni*-II was inducted into service by 2004.[144] However, persistent technical issues delayed user trials until 2009, and several subsequent launches failed due to issues with the missile's stage separation and second-stage ignition until these were apparently resolved by 2019.[145] India also possesses roughly four two-stage, solid-fuelled *Agni*-III IRBMs, which have an estimated range of 3,500 km. Like the *Agni*-II, the *Agni*-III appears to have suffered from technical issues, evidenced by several test-launch failures despite it having already been inducted into service by the Indian Armed Forces.[146]

India also has several different ground-launched designs under development, suggesting that New Delhi is seeking to develop a more credible conventional and nuclear deterrent. A new single-stage, solid-fuelled, road-mobile design known as *Pralay* was tested twice by the DRDO in December 2021.[147] An announcement by the DRDO that *Pralay* will be armed with a conventional warhead – along with the system's mobility and the missile's apparent quasi-ballistic trajectory, advanced guidance package and short launch time – demarcates India's first dedicated conventional ballistic missile for regional war fighting, the absence of which thus far has likely been a driver behind *Pralay*'s development.[148] A dedicated conventional SRBM would also reduce the possibility of miscalculated nuclear escalation in the event of a conflict with China or Pakistan because of warhead ambiguity, as both of India's existing SRBMs – the *Agni*-I and *Prithvi*-II – are dual-capable.

India's efforts to develop multiple types of longer-range systems, such as the *Agni*-P, *Agni*-IV and *Agni*-V, are likely driven by a desire to enhance the credibility of its nuclear deterrent. The *Agni*-P is described by the DRDO as 'a new generation advanced variant of *Agni* class of missiles', an apparent reference to the missile's incorporation of advanced guidance and propulsion technologies that have been developed for the *Agni*-IV and *Agni*-V.[149] The missile reportedly has a 1,000–2,000-km range, roughly placing it within the range threshold of the current *Agni*-I and *Agni*-II, both of which the *Agni*-P could potentially replace in a nuclear role.[150] Imagery released of test launches shows that the missile is stored in a sealed canister.[151] A canister protects the missile from external elements and allows for permanently mating the missile with its warhead. While a move toward canisterisation would increase the readiness of India's missile forces, it would also reduce its options for nuclear signalling in a crisis, thereby possibly increasing the prospect of crisis instability.

The two-stage, solid-fuelled, road- and rail-mobile *Agni*-IV has an estimated range of up to 4,000 km and there have been suggestions by Indian analysts that it will replace the *Agni*-II once sufficient numbers are available.[152] Following a test by India's Strategic Forces Command on 6 June 2022, an Indian government press release stated that the test was a 'successful training launch'.[153] Conversely, earlier statements from the Press Information Bureau announcing previous *Agni*-IV launches described these as 'flight tests' or as part of a 'user trial', suggesting the system was still being developed.[154] This suggests

SOLID AMBITIONS
The Indian *Agni*-V ICBM is launched successfully, April 2021. India is developing longer-range solid-fuel ballistic missiles. CREDIT: Pallava Bagla/Corbis News/Getty Images

that the launch may have been conducted for the benefit of the crew operating the system, rather than to test the parameters of an experimental design, possibly indicating the missile is ready to operationally enter service. The missile was also launched at night, which might have been planned to develop crew readiness.

Once it reaches IOC, the three-stage, solid-fuelled, road-mobile *Agni*-V will provide India's Strategic Forces Command with its first credible long-range ground-launched ballistic missile. The missile's exact range is unknown, but it is likely close to the IRBM/ICBM threshold of 5,000 km.[155] Due to its range, the *Agni*-V's likely purpose is to target China. Like the *Agni*-P, the *Agni*-V is also sealed in a canister. Along with the missile's mobile platform and use of solid fuel, this will improve the utility of India's China-focused missile forces.[156]

The Indian Navy previously operated a ship-launched, single-stage, liquid-fuelled ballistic missile known as *Dhanush*, which had a severely limited operational utility due to its long launch-preparation time and short range. Of greater but still limited use are the Indian Navy's *Arihant*-class SSBNs, two of which are believed to be in service. Each boat can carry up to 12 K-15 short-range nuclear-armed SLBMs.[157] India is developing two additional *Arihant*-class SSBNs, and satellite-imagery analysis of the hull of one of these appears to show it is longer than those of the original two boats, possibly indicating that it is being built with a larger missile compartment.[158] Although India is making efforts to develop a sea-based nuclear deterrent, the K-15's utility is limited by its 700-km range, meaning that it would be restricted to targets in southern Pakistan if launched from the Arabian Sea. The missile's short range also means that India's SSBNs would need to venture into the well-defended South China Sea to reach Chinese targets. To enhance the credibility of its sea-based nuclear forces, however, India's DRDO has been developing a longer-range SLBM, the K-4.[159] The K-4 is intended to have a 3,500-km range, which would allow the Indian Navy to strike targets in China and Pakistan from Indian littoral waters in the Bay of Bengal.

Pakistan's expanding ballistic-missile arsenal is comprised of short- and medium-range systems that are primarily deployed with Indian targets in mind. Many of these systems have conventional and nuclear roles as part of Pakistan's Full-Spectrum Deterrence posture, which aims to deter Indian forces from conventional strikes or incursions against Pakistan as part of its so-called Cold Start doctrine.[160] Because India is Pakistan's primary security concern, Pakistan has little need for developing missiles beyond a certain range threshold. Instead, Pakistan is seeking to improve the readiness, survivability and accuracy of its deployed and under-development systems.

Pakistan possesses six types of ground-launched ballistic missiles across the CRBM, SRBM and MRBM range threshold. At the lower end of the range spectrum, this includes an estimated 30 *Ghaznavi* (*Hatf*-III) and *Shaheen*-I (*Hatf*-IV) launchers and an unknown number of *Abdali* (*Hatf*-II) and *Nasr* (*Hatf*-IX) launch vehicles.[161] Despite possible technical difficulties with the development of some of these systems, all now appear to be in service. All of Pakistan's SRBMs use solid fuels and are launched from road-mobile transporter erector launchers (TELs). The mobility and quick launch times of Pakistan's ballistic-missile arsenal means that Indian forces would have a very small window to detect and destroy them prior to launch. Pakistan, like China, intentionally utilises a policy of warhead ambiguity as the Pakistani military has stated that *Abdali*, *Ghaznavi* and *Shaheen*-I are dual-capable, meaning they can deliver both conventional and nuclear warheads.[162] Although almost all of Pakistan's ballistic missiles are dual-capable, which would suggest that

Nasr will be operated in the same way, statements from the Pakistan Armed Forces' Inter Services Public Relations (ISPR) have omitted any reference to a conventional role, suggesting it may be a dedicated nuclear-only system.[163] *Nasr* has attracted some controversy, as its very short range of 70 km suggests the Pakistan Armed Forces intend to use it as a nuclear war-fighting system against Indian forces operating inside Pakistan.[164] At medium ranges, Pakistan possesses an estimated 30 *Ghauri* (*Hatf*-V) and *Shaheen*-II (*Hatf*-VI) launchers, which are divided in an unknown breakdown.[165]

Pakistan's ballistic-missile programme has benefitted from extensive support from China and North Korea, and many of its in-service systems are derivatives of equipment originally designed by Beijing and Pyongyang.[166] For instance, Pakistan's *Ghauri (Haft*-5) MRBM is a variant of the North Korean *Nogong*, while *Nasr* is a derivative of China's WS-2 guided rocket.[167] *Ghauri* is unusual as it is Pakistan's only liquid-fuelled ballistic missile. Given Pakistani development trends and an apparent propensity toward solid fuel, it is possible that Pakistan will replace *Ghauri* with a solid-fuelled system in the future. The under-development two-stage, solid-fuelled *Shaheen*-III is a possible contender for this role, given that its claimed range of 2,750 km puts the entirety of the Indian subcontinent within range from large parts of southern Pakistan.[168]

Pakistan is also developing an MRBM known as *Ababeel*, a three-stage, solid-fuelled system that can be equipped with MIRVs. Pakistan's Ministry of Defence has stated that its development is 'aimed at ensuring survivability of Pakistan's ballistic missiles in the growing regional Ballistic Missile Defence (BMD) environment'.[169] India's BMD programme is unlikely to provide comprehensive coverage of the entire country, and despite recent successful test launches, the eventual effectiveness of the system against Chinese or Pakistani ballistic and cruise missiles remains debatable.[170] However, the development of *Ababeel* reflects Pakistan's belief – in ways not too dissimilar from Pakistan's decision to develop *Nasr* – that it needs to maintain a credible nuclear deterrent against India's offensive and defensive conventional superiority.

Japan currently lacks a ballistic-missile capability, although the country's 2023 defence-budget request placed a high emphasis on acquiring 'stand-off defence capabilities' to improve its ability to conduct precision strike.[171] The deterioration of regional security, and qualitative and quantitative expansions of China's and North Korea's respective missile arsenals, were identified in the 2018 National Defense Program Guidelines as drivers for the Japan Self-Defense Forces to acquire stand-off capabilities.[172]

While Japan is not looking to acquire a 'traditional' ballistic missile, it is seeking to develop what the Japanese Ministry of Defense has called 'hyper-velocity gliding projectile units for remote island defense'.[173] This appears to be a conventionally armed HGV. Tokyo's intention was for the missile to be in service by 2029, but the worsening security environment has pushed policymakers to have it ready to be introduced into service by 2026.[174] The first iteration is expected to be launched from a mobile ground-launched platform with a 300–500-km range at supersonic (Mach 1–5) speeds.[175] Compared to other HGVs under development by other states, Japan's HGV has a much shorter range and slower speed, possibly because it will use a smaller rocket booster. An improved version is expected to reach hypersonic (Mach 5+) speeds and strike targets at greater distances, possibly beyond 1,000 km according to Japanese defence sources.[176] The configuration of the longer-range launch platform is currently unknown.

North Korea's ground- and sea-launched ballistic-missile programmes have evolved substantially since Pyongyang's initial acquisition of short-range unguided rockets in the mid-1960s. In part, this progress is because North Korea's leadership has prioritised ballistic-missile production and has dedicated significant investments of human, financial and material resources to achieve this objective. North Korea has also engaged in illicit missile-technology exchanges with multiple states, including China, Egypt, Iran, Libya, Pakistan, the Soviet Union/Russia, Syria and Ukraine, which

UPGRADES
The *Shaheen*-III is one of two types of MRBMs that Pakistan is currently developing. CREDIT: Aamir Qureshi/AFP/Getty Images

BLACK TORTOISE
A *Hyunmoo*-II ballistic missile is launched during a South Korean military exercise, September 2017. The *Hyunmoo* series is the backbone of South Korea's SRBM capability. CREDIT: South Korea Defense Ministry/NurPhoto/Getty Images

has accelerated its programme within a short time frame. The culmination of these efforts is a missile force capable of increasingly longer ranges, with improved accuracy and survivability that can fulfil regional war-fighting as well as strategic-deterrence roles.

Pyongyang's original motivation to develop a ballistic-missile programme was its desire to deter and coerce South Korean and US forces stationed in the region.[177] The limited range and accuracy of North Korean adaptions of Soviet-supplied technology, such as the *Hwasong*-1 (a derivative of the 3R10 *Luna*-2 artillery rocket), and Moscow's reluctance to provide Pyongyang with more advanced SRBMs, such as the *Scud*-B, however, resulted in North Korea developing a missile-technology-transfer relationship with Egypt instead.[178] Egypt's delivery of *Scud*-B SRBMs to North Korea in 1980 generated a series of upgraded indigenous derivatives from the mid-1980s, including the *Hwasong*-5, *Hwasong*-6, *Hwasong*-7 and *Hwasong*-9 variants, all of which are believed to remain in operation.[179]

Although the incorporation of propulsion and guidance upgrades provided North Korea with a more effective means to accurately strike targets throughout the Korean Peninsula with chemical, biological and high-explosive payloads, North Korea's ballistic-missile programme became progressively tied to Pyongyang's decision to develop nuclear weapons, resulting in the development of longer-range systems that could carry heavier payloads. Consequently, North Korea began developing increasingly longer-range systems in the 1990s, including the single-stage, liquid-fuelled and road-mobile *Hwasong*-10 (*Musadan*) IRBM, a derivative of the Soviet R-27 (RS-SS-N-6 *Serb*) SLBM.[180] Despite substantial technical problems with the propulsion system and multiple recorded test failures, US defence reports state that the *Hwasong*-10 was deployed in 2009.[181] The IISS estimates that North Korea possesses ten such launchers.[182]

The *Hwasong*-10's problematic development spurred North Korean designers to seek an alternative propulsion system for improved reliability.[183] The resultant single-stage, liquid-fuelled and road-mobile *Hwasong*-12 (KN-SS-17) IRBM was first successfully tested in 2017 and appears to have far fewer technical glitches than its problematic predecessor. Analysts believe that North Korea's rapid technological progression was probably facilitated by the illicit transfer of design material from Ukraine's Yuzhmash plant, as the *Hwasong*-12's propulsion unit appears to be based on the Yuzhmash-designed RD-250 engine.[184]

The opacity of North Korea's ballistic-missile programme, as well as Pyongyang's readiness to use it for propaganda purposes, has meant that there is uncertainty regarding the service status of some of its more recent designs. The three-stage, liquid-fuelled and road-mobile *Hwasong*-13 (KN-SS-08) ICBM and the two-stage, liquid-fuelled *Hwasong*-14 (KN-SS-20) ICBM are illustrative examples of this problem. While the former was paraded in 2012, it has apparently never been tested, leading some analysts to suggest that it was either a developmental design or simply a propaganda mock-up.[185] Although the *Hwasong*-14 made two successful test flights in July 2017, thereby becoming the first North Korean missile capable of reaching the United States' eastern seaboard, its service status is also uncertain according to US government reports.[186] North Korea has further improved upon the *Hwasong*-14's design with the development of the road-mobile, two-stage, liquid-propellant *Hwasong*-15, which uses an enlarged first and second stage derived from the *Hwasong*-14.[187]

Beyond SSMs, North Korea is also striving to develop a usable SLBM design through the *Pukguksong* series. After successfully testing the two-stage, solid-fuelled *Pukguksong*-1 (KN-SS-N-11) in 2016, North Korea has test-launched two other variants of the missile, the two-stage, solid-fuelled *Pukguksong*-2 (KN-SS-15) and the *Pukguksong*-3 (KN-SS-N-26).[188] It has also paraded two other variants, the *Pukguksong*-4 and *Pukguksong*-5. It appears that North Korea intends to use some of the *Pukguksong* series in a ground-launched role, evidenced through a dedicated TEL being utilised during a 2017 test of the *Pukguksong*-2.[189] Pyongyang's decision to derive a ground-launched missile from an SLBM may have been an effort to shorten the development time frame to acquire a solid-propellant system, since most of North Korea's longer-range SSM inventory is comprised of liquid-fuelled systems. Despite North Korea's efforts to develop an SLBM capability, the limitations of its conventionally powered ballistic-missile submarine force means that its sea-based deterrent will likely have limited utility compared with its much larger and more survivable land-based forces.

The trajectory of North Korea's ballistic-missile programme for the foreseeable future was laid out by President Kim Jong-un at the 8th Congress of the Workers' Party of Korea in 2021, with its goals including the development of tactical nuclear weapons; an ICBM with a 15,000-km range; HGVs; and solid-fuelled ICBMs.[190] It has made mixed progress in achieving these ambitions, claiming to have successfully tested two types of re-entry vehicles in 2021 and 2022 that display HGV properties – a wedge-shaped system known as the *Hwasong*-8 and an unnamed, conically shaped glider that appears outwardly similar to a traditional manoeuvrable re-entry vehicle (MaRV).[191] Whether these are competitive designs is unknown, as are these systems' levels of accuracy, speed and ability to conduct substantial cross-range manoeuvres. It is likely that North Korea is pursuing an HGV in order to better penetrate existing and future missile defences, as well as for propaganda purposes.

Of Kim's other ambitions, the *Hwasong*-17 ICBM provides North Korea with a credible means of developing a very-long-range ICBM. Although the *Hwasong*-17 appears to have suffered from technical problems during flight tests, the propaganda value of possessing extremely large systems is likely not lost on North Korea's leadership, considering the state-produced fanfare around test launches.[192] Although the missile's precise range is unknown, Japanese defence officials estimate it to be around 15,000 km.[193] It is likely the *Hwasong*-17 has an extremely high throw-weight, allowing for the carriage of MIRVs and decoys for greater penetrability of missile defences. US officials have stated that North Korea appears to have tested a post-boost vehicle under the guise of a satellite launch.[194] However, the missile's enormous size raises questions about its readiness and utility.[195]

North Korea appears to have had greater success in developing solid-propellant SRBMs than solid-propellant ICBMs, given the substantial number of test launches of these systems in 2021 and 2022. This includes the single-stage, solid-fuelled and road-mobile KN-23 and KN-24, as well as the KN-25 MLRS.[196] Some analysts have suggested that the KN-23 is a likely candidate for a non-strategic nuclear-weapons delivery vehicle.[197] At longer ranges the aforementioned *Pukguksong* series might provide one pathway to developing a solid-fuelled ICBM, although the likeliest variant – the *Pukgoksong*-5 – is not believed to have been tested.[198]

South Korea's ballistic-missile programme has periodically evolved alongside developments in North Korea's ballistic arsenal and nuclear-weapons programme and plays a key role in Seoul's deterrence architecture. Prior to 2008, South Korea only possessed a limited number of *Nike Hercules* IIs, a single-stage, solid-fuelled SRBM reverse-engineered from the United States' MIM-14 *Nike Hercules* surface-to-air missile.[199] The missile's 180-km range was designed to comply with the 1979 Memorandum of Understanding (MoU) signed between Washington and Seoul that prohibited South Korea from developing ballistic missiles with ranges greater than this and placed restrictions on the size of warheads.[200]

North Korea's first nuclear-weapons test in October 2006 and the growth of its ballistic-missile arsenal prompted South Korea and the US to periodically agree to loosen the 1979 MoU's range and warhead size restrictions. Following alterations in 2001, 2012, 2017 and 2020, the agreement was finally terminated in 2021, thereby lifting any restrictions on South Korea's development of ground-launched ballistic missiles.[201] These incremental changes have allowed South Korea to develop increasingly more lethal systems, providing it with greater targeting options. For instance, with the total lifting of warhead weight restrictions in 2017, South Korea subsequently tested a single-stage, solid-fuelled SRBM known as *Hyunmoo*-4, which features a 2,000-kg warhead, one of the world's heaviest payloads.[202]

South Korea's ballistic-missile inventory is currently mostly based around variants of the *Hyunmoo*-2, a single-stage, solid-fuelled SRBM that was first revealed in 2008 following revisions to the range restriction that raised the cap to 300 km. South Korea has subsequently deployed two additional variants of the missile, the *Hyunmoo*-2B and *Hyunmoo*-2C, with respective ranges of 500 km and 800 km. The *Hyunmoo*-2C has control surfaces which allow it to manoeuvre during the terminal phase of its flightpath.[203]

CRUISING
Australia already possesses JASSM cruise missiles and is set to receive an extended-range variant. CREDIT: Richard Baker/In Pictures/Getty Images

Beyond the land-based *Hyunmoo* series, South Korea has also developed a conventionally armed SLBM – a unique capability, as other navies that operate these types of systems have instead armed them with nuclear warheads.[204] The missile is to be deployed aboard the *Chang Bogo* III (KSS-III) class of submarines, the first of which, the ROKS *Dosan Ahn Changho*, was commissioned in August 2021 and made its first deployment in August 2022.[205] From Seoul's perspective, an SLBM would provide a means of rapidly engaging targets that could otherwise be deployed outside the range of Seoul's ground-based SRBMs.

South Korea's motivation to develop conventionally armed ground- and sea-launched ballistic missiles is part of Seoul's deterrence-by-denial and punishment strategy to deter North Korea from using nuclear weapons. Its goal is to be able to detect North Korean missile-launch preparations and to engage the missiles prior to firing, a cycle that reportedly takes less than 25 minutes.[206] This so-called 'kill-chain' doctrine was tamped down under the previous Moon administration, but South Korea's new President Yoon Suk-yeol has since reversed this attempt to placate North Korea.[207]

Indo-Pacific Cruise

Given the geography of an increasingly tense environment, long-range LACMs have and continue to find favour with many countries in the Indo-Pacific. Domestic developments sit alongside off-the-shelf acquisitions, with China, Russia and the US all supplying one or more countries in the region. Bilateral security dynamics also propel some developments. Several countries are pursuing weapons-related hypersonic technology, either at the national level or in partnership.

Australia ordered the US AGM-158A JASSM in 2006, with the 300-km-plus-range weapon being introduced into service in 2011. In July 2022, the US Defense Security Cooperation Agency released a notification of the approval for sale of the AGM-158B JASSM-ER, which has a range of over 900 km. This air-launched LACM will be carried by the Royal Australian Air Force's Boeing F/A-18F *Super Hornet*s and its F-35As. A quarter of a century after Canberra first expressed interest in the RGM/UGM-109, a *Tomahawk* purchase is again being considered.[208] The rationale, as with the JASSM-ER, is to acquire much longer-range LACMs to improve launch-platform survivability and to hold a greater variety of targets at risk.

The 2021 tri-national AUKUS agreement, furthermore, is also providing a vehicle for Mach 5+ weapons research between Canberra, London and Washington. This may well build on previous Australia–US research work including the Southern Cross Integrated Flight Research Experiment (SCIFiRE) to develop a prototype Mach 5-class ALCM.[209]

Very-high-speed weapons aspirations are also shared by South Korea, which suggested in 2020 that it was pursuing Mach 5+ LACM development.[210] Seoul already fields air- and ground-launched LACMs of varying ranges. It selected the KEPD-350 *Taurus* in 2013, an acquisition notable not least because it saw a non-US ALCM integrated on US combat aircraft, in this case the Boeing F-15K *Slam Eagle*. A domestic ALCM missile, *Chun Ryong*, is also in development.[211] The *Hyunmoo*-3 GLCM is also in service, as is the *Hae Sung* III submarine-launched LACM. The latter has an estimated range of 1,500 km. South Korea's cruise missiles and planned developments are central to its doctrine in dealing with the perceived threat from North Korea.

North Korea's missile threat has previously been built on its array of surface-to-surface ballistic systems, but it is now in the final stages of developing a 1,000-km-plus-range GLCM.[212] Two domestic subsonic cruise-missile designs were first shown at a North Korean defence exhibition in October 2021, and flight-test footage has also been released.[213] Pyongyang may also be pursuing an ALCM.[214] North Korea and Iran are assessed to have previously cooperated not only on ballistic systems, but also on cruise-missile-related technology.

A similar dynamic is apparent between India and Pakistan, with weapons acquisitions tailored to meet specific threats. In the case of the former, India also must consider its relationship with China, which has been a source of some of Pakistan's land-attack missile capacity, as well as its main source generally of military equipment. The *Hatf* VII/*Babur* GLCM likely benefitted from Chinese technical support.[215] The Pakistan Air Force's inventory includes the *Hatf* VIII/*Raad* I and *Raad* II ALCM missiles.[216] The *Raad* II is an extended-range variant, with a range of 600 km. Both *Babur* and *Raad* fulfil conventional and nuclear roles.

India, meanwhile, acquired a 300-km-plus-range LACM through its relationship with Russia and development of the NPO Mashinostroyenia 3M55 *Onix* (RS-SS-N-26 *Strobile*). Acquired initially as a supersonic anti-ship weapon, India also now fields the *Brahmos* variant as a ground-launched LACM. An air-launched version, the *Brahmos* A, an 800-km-range variant of the missile, is also in development.[217]

While using Russian missile technology as the basis for domestic Indian variants has proved a success, a national cruise-missile project has so far proved less successful. First tested in 2013, the Aeronautical Development Agency's *Nirbhay* programme has suffered several failures, has not entered service and is described now as a technology demonstrator.[218] As of late 2022, India was working on a further development of *Nirbhay* known as the Indigenous Technology Cruise Missile (ITCM). This replaces a Russian-sourced turbofan with a domestic engine, the *Manik*. Like the *Nirbhay*, the ITCM has suffered from test failures.[219]

Along with the subsonic *Nirbhay*/ITCM, India is looking at very-high-speed cruise-missile technology, again in part in cooperation with Russia. The *Brahmos* II is intended to be a Mach 5+ cruise missile, with the DRDO again working with NPO Mashinostroyenia.[220] The extent of the development of this project is unknown. The DRDO Hypersonic Technology Demonstrator Vehicle (HSTDV) is a scramjet-engine test bed, possibly supporting the *Brahmos* II project. At least two test launches of the HSTDV have taken place, the first in 2019 and the second in 2020.[221]

Very-high-speed cruise-missile technology is also being developed in Japan, in part a reflection of the shift in Tokyo's defence posture to more offensive capabilities.[222] At the same time, it is pursuing a 1,000-km-class subsonic low-observable LACM, while also considering the purchase of the US RGM/UGM-109 *Tomahawk*.[223] The former, sometimes described as an upgrade of the Type 12 anti-ship missile, appears rather to be a new missile. Supporting its HCM ambitions, Japan is developing a scramjet engine. A first flight test of engine-related technology was carried out in July 2022. Japan has furthermore ordered the Kongsberg JSM for its F-35A aircraft and is also aiming to acquire the US AGM-158B for its F-15s.[224]

Even more so than Japan, Taiwan's cruise-missile projects are aimed at helping to deter or counter threats from China. The country has subsonic and supersonic cruise missiles in its inventory. The *Hsiung Feng* IIE designation is associated with a land-attack derivative of the subsonic *Hsiung Feng* II anti-ship missile, while the 250-km-plus *Wan Chien* ALCM is in production for the Taiwanese Air Force's Aerospace Industry Development Corporation's F-CK-1 *Ching Kuo* combat aircraft.[225]

Conclusion

That ballistic and cruise missiles are proliferating is evident. There has been an unprecedented resurgence in demand for the former, driven by their improved utility as conventional weapons. Although the number of ballistic-missile operators was curtailed by multiple arms-control and counter-proliferation initiatives in the post-Cold War period, this trend has begun to reverse as multiple states across different regions are reconsidering them as practical weapons. While some states are procuring these systems from allies, others are making concerted efforts to develop them either independently or with foreign assistance. Moreover, cruise missiles are no longer the purview only of states, let alone nuclear-weapons states, given that at least one NSA has received an LACM from a state backer. Although arms-control and non-proliferation mechanisms, such as the MTCR and the Wassenaar Arrangement, can slow down procurement or development programmes, they are ultimately unable to halt them, given illicit technology transfers, the dual-use nature of many missile components and lowering technological barriers for the development of the latter. Some states, such as Iran and North Korea, provide illustrative examples of how a state can develop a sophisticated and diverse missile programme from humble beginnings. Given this proliferation challenge, an evaluation of existing frameworks and the means to improve them should be considered.

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Global Control of Missile Proliferation

CHAPTER
SEVEN

This chapter examines existing global frameworks to limit the spread of missiles and other armed uninhabited aerial vehicles (UAVs). Three agreements address missile proliferation and their related technologies: the Missile Technology Control Regime (MTCR), the Hague Code of Conduct against Ballistic Missile Proliferation (HCoC), and United Nations Security Council Resolution (UNSCR) 1540. This chapter will describe the scope of these agreements, along with their current state of play in international forums, and discuss potential recommendations for reform.

Three Global Regimes

The MTCR, the HCoC and UNSCR 1540 together provide an overall framework for the governance of the proliferation of missiles and other systems likely to deliver weapons of mass destruction (WMD). Despite the successes and positive contributions of these agreements, the vertical and horizontal proliferation of ballistic and cruise missiles continues apace among state actors and increasingly also among non-state actors. In addition, increased access to advanced missile-design capabilities and manufacturing processes has led to increases in the speed, accuracy and range of these systems, at an ever-lower cost. Innovation, especially in conflict, has further advanced and spread weapon designs and reshaped the balance of power in several regions, including the Asia-Pacific and the Middle East. The return of great-power competition between China, Russia and the United States, combined with a concomitant rise in tensions, further drives arms racing for missiles and armed UAVs. There is therefore an urgent need for further reforms – both incremental and radical – in order to restrain proliferation activity.

The Missile Technology Control Regime

Specifications

The MTCR is a technology-focused export-control regime, comprising a voluntary association of 35 member states that apply agreed standards

Key takeaways

AN ERODED ARCHITECTURE
The return of great-power politics, resurgent nationalism and the collapse of consensus and indeed confidence in collective security and multilateralism has caused severe damage to the global arms-control, disarmament and non-proliferation architecture.

INSUFFICIENT CONTROLS
Non-proliferation mechanisms have slowed some states' ballistic- and cruise-missile programmes. However, regional tensions and great-power competition are driving national interest and innovation in procuring or developing new missile designs, straining non-proliferation efforts.

LIMITATIONS OF REGIMES
Despite the strengths and successes of non-proliferation mechanisms such as the Hague Code of Conduct, the Missile Technology Control Regime and United Nations Security Council Resolution 1540, these mechanisms' institutional shortcomings, limited scope and opacity, amongst other weaknesses, suggests that reform is urgently needed.

NECESSARY IMPROVEMENTS
Implementation, verification and enforcement should be at the heart of efforts to improve non-proliferation mechanisms going forward, alongside trying to improve transparency of these frameworks' internal processes and deliberations.

RADICAL REFORM
At a more radical level, synchronisation or even combining these mechanisms under a United Nations mandate would increase the reach and legitimacy of missile controls.

('Guidelines for Sensitive Missile-Relevant Transfers') designed to limit the export of technology that can be used for the uncrewed delivery of WMD.[1] It was established by the G7 on 16 April 1987 to address the proliferation of nuclear-capable missiles, in particular by the Soviet Union and China but also through indigenous programmes in Argentina, Brazil, India, Israel, Pakistan and South Africa.[2] The MTCR was part of a global *acquis* to control missiles, alongside US–Soviet Union bilateral arms-control initiatives – especially the Intermediate-Range Nuclear Forces Treaty (INF), which was concluded two days before the MTCR was announced.[3] The MTCR initially focused on missiles (along with components, technology and related equipment) capable of delivering a 500-kilogram warhead to a 300-kilometre distance.[4]

The MTCR Guidelines include a detailed Annex which defines complete delivery systems and production facilities (Category I items), as well as supporting equipment, software and technologies that could contribute to building delivery systems (Category II items).[5] The Annex contains clear guidance on the transfer of these items, requiring that six factors must be taken into account: concerns regarding WMD proliferation, the nature of the recipient's missile and space programmes, the relationship between the transferred technology and WMD-delivery capabilities, the specific end use of the technology, the relationship to other agreements, and the risk of proliferation to non-state actors.[6]

Governance

France serves as the Point of Contact (POC) for the MTCR, with an informal secretariat based in Paris. To support and maintain the regime, MTCR member states convene through three sub-groups – the Technical Experts Meeting (TEM), the Information Exchange Meeting (IEM) and the Licensing and Enforcement Experts Meeting (LEEM) – and a plenary session, each of which takes place annually.

There are also monthly POC meetings in Paris, attended by representatives from member states' local embassies, and intercessional Reinforced Point of Contact (RPOC) meetings in April or May.[7] Individual member states volunteer to serve as the rotating annual MTCR chair, as part of the MTCR Troika composed of the previous, current and next chair countries. The current chair is Switzerland (Ambassador Benno Laggner). The chair is expected to lead outreach efforts, including Technical Outreach Meetings (TOMs), for MTCR partners and non-partners alike.[8]

MTCR membership is limited to states with significant capabilities related to missile-delivery systems, space-launch vehicles (SLVs) and associated technologies. The MTCR's work is confidential, with expert working groups exchanging sensitive information in order to derive useful guidelines for export controls. The MTCR Annex includes a set of definitions of the highest technical complexity and is continually updated by experts from each of the member states. The Annex is used in a number of formats, including sanctions regimes and other export bans in UN, bilateral and other multilateral contexts. The MTCR provides all partner states with support to create and implement export controls consistent with the Guidelines. To date, Estonia, Kazakhstan and Latvia have been conferred status as formal MTCR adherents, with Israel, North Macedonia, Romania and Slovakia pledging their own unilateral compliance.[9] Cyprus and Iraq have pledged to adopt the Guidelines as part of their implementation of UNSCR 1540, and China has also pledged adherence to them although suspicions remain about its proliferation record.[10]

SCUD

The *Scud* missiles' 300 km-range and 500 kg-warhead became the basis for MTCR export controls. CREDIT: Photo by Robert Wallis/Corbis via Getty Images

Evolution

In 1992 the member states expanded the MTCR to address all WMD, and UAVs, target drones and cruise missiles.[11] They also called on all other states to declare themselves 'universal adherents' to the regime and to agree to apply the MTCR Guidelines. After the 11 September 2001 attacks in the US, the MTCR's goals were expanded to address transfers to non-state actors, reinforced by UNSCR 1540.[12]

EXPANSION
The MTCR was updated in 1992 to include new types of equipment, such as target drones. CREDIT: Photo by IDF/Handout/Hulton Archive via Getty Images

The MTCR also includes the concepts of 'particular restraint' on sales and exports, and a 'presumption of denial' standard for the most concerning systems and their enabling technologies. However, the MTCR's focus on WMD delivery somewhat undermines its effectiveness, especially as higher-precision conventionally armed systems are increasingly becoming the norm. At the time of the original MTCR negotiations, ballistic and cruise missiles were mostly inaccurate – with limited exceptions such as the United States' UGM-109C *Tomahawk* land-attack cruise missile (LACM) – and therefore ballistic missiles in particular would have required a nuclear warhead in order to have a reliable effect on their targets.

The MTCR also contains three other important principles: 'no undercut', 'catch-all' and 'intangible technology transfer'. The 'no undercut' policy, introduced in 1994, specifies that partners and adherents will not undermine each other by granting an export licence when another state has already denied it based on the MTCR Guidelines (these concepts are also used by the Australia Group and the Nuclear Supplies Group).[13] The 'catch-all' provision, added to the Guidelines in September 2003, allows all regime partners to deny exports of items not included in the MTCR Annex if it is known that they will support a missile programme.[14] It followed the adoption of similar provisions by the Australia Group in 2002.[15] The MTCR Annex was also expanded to include 'intangible' technology transfers (of software, for example) in 2003.[16]

Strengths

The MTCR has had several notable successes since its signing. Firstly, despite being a supply-side arrangement, it has evolved into a global norm that has increased security and helped restrain missile proliferation. This has occurred despite the absence of a universal and legally binding treaty within the UN framework. The regime's 35 member states include many of the most important possessors and producers of missiles and related technologies. By limiting membership to states that possess the most advanced delivery systems and related technologies, the MTCR's three expert working groups operate at the highest levels of detail. The resulting MTCR Annex is an impressive document, with an agreed scope and a set of definitions of the highest technical complexity. The expertise provided by MTCR working-group members also means the Annex is continually updated by world-leading experts on missile technology and export control. The Annex features such an extraordinary level of detail, relevance and scope that it has been used as the basis for missile-technology controls enacted under other UNSC resolutions.[17] The MTCR's programme of outreach to non-member states has supported them in adopting the MTCR's controls through the 'adherent' system and aligning their export controls. The transparent adoption of standards and the regular outreach is a major step forward in formalising a previously informal process.

Together, these factors have played a role in slowing or stopping several significant missile programmes, including ending the joint Argentine–Egyptian–Iraqi

OMISSIONS
Some missile producers and exporters, such as China, are not MTCR members. CREDIT: Pool/Pool by Getty Images

Condor II ballistic-missile programme; eliminating the missile stockpiles of former Warsaw Pact states that had aspirations to join the European Union, NATO and the Non-Proliferation Treaty (NPT); (temporarily) impeding the missile programmes of India and South Korea; and eliminating Libya's Category I missiles.[18] Although other factors, including diplomatic and economic pressures and incentives, encouraged these positive outcomes, the MTCR played an important contributory role.

Weaknesses

No agreement focused primarily on the supply side, no matter how extensive, can completely prevent a state from developing an indigenous missile programme if it is willing to commit resources and time to such a programme. The MTCR can delay, complicate, and raise the political and economic costs of such a decision, but it cannot ultimately prevent or roll back missile proliferation. Also, the MTCR is a voluntary regime, outside the UN *acquis*, and relies on self-enforcement, with no verification or enforcement mechanisms. The complaint from some non-members that the MTCR is a discriminatory cartel means that adherence in some regions is limited.[19] China, Iran, Israel, North Korea and Pakistan are well-developed producers of ballistic and, in some cases, cruise missiles, while Saudi Arabia, Taiwan and the United Arab Emirates have serious ambitions to achieve indigenous design and production capabilities – but all of these states remain outside the MTCR. China and Israel in particular conduct a robust trade in UAVs, while conflicts in the Middle East have demonstrated that non-state actors have access to precision-guided unmanned delivery systems, including ballistic and cruise missiles and UAVs.[20] Romania has applied to join the MTCR, as have some other states with advanced technological capabilities, but as a NATO member its membership has been blocked by Russia.

For states with ongoing acute security dilemmas – such as India, Iran, North Korea, Pakistan and South Korea – the creation of supply-side limitations on the acquisition of missiles and related technologies has proved insufficient to close off all routes to pursue advanced missile capabilities. Limiting access has raised the price and time needed for acquisition, but because the underlying security dilemmas driving missile procurement have not been solved, such countries have eventually been able to acquire the necessary technology and material to create domestic missile-manufacturing capabilities. The case of China is also instructive in illustrating the limitations of the MTCR. The MTCR was negotiated in part to address Chinese proliferation of missiles and missile technology (especially to Saudi Arabia) in the 1980s.[21] In 1991, in confidential correspondence with the US, China signalled that it intended to abide by the MTCR and stated a commitment to implementation in 1992.[22] However, despite strengthened commitments in 1994 and 2000, and a formal application to join the MTCR in 2004, scepticism about Chinese intentions remain.[23] Chinese firms continue to be sanctioned for missile proliferation, with additional questions about cooperation with Saudi Arabia arising in 2007 and

2019, and there are suspicions regarding possible Chinese efforts to exploit Ukrainian ballistic-missile expertise.[24]

The MTCR also has significant institutional weaknesses. These include a rule that decisions need to be made by consensus, the lack of a permanent secretariat, limited technical expertise on the part of some partner and adherent states, and an absence of controls on vertical proliferation. The need for consensual decisions has made it more difficult to address rapid changes in technology, especially regarding UAVs. The lack of a permanent secretariat places the burden of supporting MTCR meetings on France, the host country, and limits the institutional engagement of member states when compared with other multilateral institutions. Despite the creation of the leadership troika, the rotating chair has led to inconsistent leadership and a lack of consistent momentum for change – for instance it has passed from South Korea to Russia and then most recently to Switzerland, three countries with wildly diverging priorities. The EU has sought to address this shortcoming by providing funding to support implementation, but many states in the Non-Aligned Movement see the EU as anything but an impartial party.[25]

HCoC overview

Specifications

The HCoC is a politically rather than legally binding commitment by 143 states to curb the proliferation of ballistic missiles capable of delivering WMD, and 'to exercise maximum possible restraint in the development, testing, and deployment' of such missiles.[26] It recognises the similarities between SLV and ballistic-missile programmes, and the rights of states to pursue peaceful space exploration. It is a brief, three-page document with no definitions or annexes, it is open to all states, and it commits its members (referred to as 'subscribers') to a variety of transparency measures.[27] These include an annual declaration of ballistic-missile and SLV policies, and of the numbers and classes of ballistic missiles and SLVs launched in the previous year, as well as pre-launch notifications (PLNs) of ballistic-missile and SLV tests and launches, and encouragement to subscribing states to organise visits to SLV launch facilities.[28] The HCoC contains no verification or compliance measures.

Governance

The HCoC has a voluntary chair system, currently occupied by Nigeria. The subscribing states convene in a two-day Annual Regular Meeting (ARM) in Vienna (the most recent was the 21st ARM on 10 May 2022) to take decisions, with intersessional working meetings also organised. The Austrian foreign ministry serves as the Immediate Central Contact (Executive Secretariat) and also as the host and informal secretariat of the ARM. In addition to this support from Austria, the EU provides significant annual funding for the outreach and implementation of the HCoC and helps to design and implement outreach activities, including side events, research papers, expert meetings and regional awareness seminars. These activities are carried out under the EU's 2003 strategy against proliferation of WMD and subsequent Council Decisions in support of the HCoC and conducted by the Foundation for Strategic Research (FRS) with the involvement of the HCoC chair.[29] The most recent renewal of support came on 25 November 2021, when the European Council extended the current programme of support until 21 January 2023.[30]

Evolution

The HCoC was proposed in 2000 and opened for signature on 25 November 2002 in The Hague. It was negotiated among the MTCR partners, who were mindful of the ongoing and accelerating proliferation of nuclear-capable ballistic missiles, especially in the context of the rapid advancements of the North Korean nuclear and missile programmes in the 1990s.[31] The HCoC was also intended to create equal obligations for all subscribers and to include 'demand side' norms, rather than just the 'supply side' rules of the MTCR. It aims to legitimise the pursuit of peaceful technologies related to missile technology, such as SLVs. In this respect it has more similarities with the NPT, which seeks to legitimise peaceful cooperation on nuclear

SLV
The HCoC does not impede states from pursuing national space programmes. CREDIT: Jody Amiet/AFP by Getty Images

applications, than with the conventions on landmines and cluster munitions, which seek outright bans. The HCoC has not evolved significantly over the decades and does not apply to cruise missiles or UAVs.

Successes

The HCoC has several strengths and successes: a very broad membership (143 of the 193 UN member states); the establishment of a global norm against the use of ballistic missiles (admittedly not very effective in light of current conflicts), and of the right of states to pursue the peaceful use of SLVs; a confidence-building measure regarding transparency on ballistic-missile stocks, tests and policy, and on space programmes, launches and policy; and a global risk-reduction measure on pre-launch notification of missile and SLVs (again with patchy compliance). [32]

Despite the initial misgivings of some states, the HCoC quickly achieved wide membership, with 93 subscribing states at its opening in 2002 and 143 today, with still more UN members voicing support for it in the UN General Assembly (UNGA) First Committee resolution in support of the HCoC in October 2022 (170 countries in favour, one against, ten abstaining), which is due to be voted on in the UNGA in December 2022.[33] HCoC outreach continues apace, with a side event at the UNGA on 11 October 2022 and an event promoting the HCoC at the United Nations Institute for Disarmament Research (UNIDIR) Space Security Conference on 1 November 2022.[34]

The HCoC complements the MTCR by addressing demand-side issues, including by recognising that missile proliferation is driven by regional and global security challenges. It complements other efforts to stop or limit the spread of missile technology to state and non-state actors. By focusing on ballistic missiles, it draws attention to some of the most dangerous missile systems, notably dual-capable systems and those with increasing range, accuracy, mobility and concealability. The agreement also covers close- and short-range ballistic missiles (CRBM and SRBM respectively), which are often forward deployed in 'use or lose' situations, further exacerbating crisis instability.

By being transparent about their ballistic-missile holdings and policies, subscriber states can help reduce the risks of misinterpretation and open a dialogue with other states concerned about ballistic missiles. Similarly, transparency over space programmes and policy can foster dialogue to reduce misunderstandings and encourage appropriate cooperation. Transparency over SLV and ballistic-missile launches can help reduce risks of unintentional conflict or escalation. There also remains space within the HCoC for the development of further confidence-building measures (CBMs) and transparency measures, although none have been adopted since the HCoC's launch.

Weaknesses

The HCoC has notable weaknesses, most of which stem from its original context and from a marked failure to expand its scope and strength through additional CBMs, although that was originally envisioned and also discussed during the earliest ARMs.[35] Its membership, although wide, still does not include key possessors or producers of ballistic missiles such as Algeria, Brazil, China, Egypt, Iran, Israel, North Korea, Pakistan, Saudi Arabia, Syria, Taiwan, Vietnam or Yemen. There remains no formal linkage between the HCoC and UN processes or the NPT *acquis*. The code does not apply to cruise missiles or UAVs, and thus does not align with the MTCR or adequately address global missile trends, with the number of states operating these systems having increased substantially in the last 20 years.[36] Like the MTCR, the HCoC is politically binding and relies upon self-reporting, with no verification or enforcement and weak institutional support – compliance remains patchy at best. Further problems with compliance come from a lack of clear definitions, particularly regarding notifications and policies. The introduction of pre-filled 'nil' forms for states that do not have ballistic missile or space programmes has increased reporting rates, but also reflects the fact that many countries did not bother to submit declarations.[37]

The HCoC was originally negotiated among the MTCR member states, leading to accusations that it represents the interests of the West, and its scope was limited by US president George W. Bush's administration being sceptical about the value of multilateralism and placing greater value on 'coalitions of the willing' in pursuing non-proliferation goals.[38] The HCoC's member states continue to lack ambition when it comes to expanding the code or pressing for full implementation. Few, if any, changes were agreed in two rounds of consultations before the code was opened for signature in 2002, and the final agreement remains largely as the MTCR member states drafted it. In the UN, Egypt has been a leading critic of the HCoC, complaining about its limited scope and lack of institutionalised cooperation to promote the sharing of the benefits of the peaceful uses of space-launch technology. However, Egypt's complaints also relate to Israel's refusal to join.[39]

The issue of transparency over space programmes is a further shortcoming of the HCoC, as several states that have declared their intention to launch such programmes have not joined, including Laos, Myanmar and Sri Lanka. Moreover, there is no means for institutions or non-state actors with space policies or programmes to join, which excludes, for example, the African Union, the EU, NATO, Blue Origin, SpaceX and Virgin Galactic. There is evidently insufficient expertise and political engagement on the part of the HCoC, stemming in part from the lack of a permanent professional and international secretariat, as well as the disconnect between technical experts and political leadership. The political will to reform the HCoC is largely absent – as suggested by the fact that over the last ten years, on average, only about half the members states have attended the ARM.[40] The lack of compliance with regard to annual declarations and pre-launch notifications among member states, especially the US and Russia, is notable. Compliance statistics are difficult to generate because information exchanged under the HCoC is not shared publicly, but it is known that the US did not share PLNs from 2002–10 and that Russia suspended its PLNs from 2008–10, and that by 2018 overall compliance had dropped below 70%.[41]

The HCoC's failure to limit or even address the spread of ballistic missiles to non-state actors, or to address cruise missiles or UAVs in any way, has also been discouraging. Furthermore, the link between ballistic missiles and WMD delivery is weaker than it used to be, as more states and non-state actors are using increasingly accurate ballistic missiles for conventional missions. For example, Russia has employed highly accurate 9K720 *Iskander*-M (RS-SS-26 *Stone*) and less accurate 9K79 *Tochka*-U (RS-SS-21 *Scarab*) SRBMs in Ukraine, to devastating effect. Other types of missiles which can blur definitional boundaries, such as hypersonic boost-glide vehicles (HGVs), are in service in China and Russia, with several other states including France, Japan and the US likely to operate these systems within the next ten years. As for UAVs, their combat capabilities have increased significantly in the last two decades, making them increasingly capable platforms.[42] These developments further call into question the HCoC's focus on ballistic missiles. Germany has tried to include cruise missiles in the HCoC, but not succeeded.[43] Meanwhile, non-state actors such as Hizbullah and Ansarullah have been supplied with anti-ship and ballistic missiles (and LACMs too, in the case of Ansarullah), and have used them against both military and civilian targets in the Middle East.

Finally, since the initial draft HCoC agreement was shared with prospective members in 2002, it is notable that not a single proposal to strengthen its implementation, widen its scope or add additional CBMs has succeeded, which underlines some of the difficulties in realising the agreement as it currently exists. However, the accelerating trends in missile proliferation, and the related spread of technology, know-how and other intangibles, lead to the conclusion that something must be done. The following section sets out some key threats, both to the HCoC and the MTCR, that strongly suggest the need for change.

PROLIFERATION
Houthi militants launching a ballistic missile in Yemen in 2018. CREDIT: Contributor/AFP by Getty Images

UNSCR 1540

Specifications

UNSCR 1540 (2004), 1673 (2006), 1810 (2008), 1977 (2011) and 2325 (2016) are five related Security Council resolutions created in part to address the loophole of missile proliferation to non-state actors, but also to limit UN member states' cooperation with NPT non-member states that possess or are seeking nuclear weapons.[44] All 193 UN members are members of UNSCR 1540. After the terrorist attacks of 11 September 2001 and the discovery of a black-market nuclear-proliferation network organised by Pakistani scientist A. Q. Khan, many countries realised there was a lack of national legal frameworks to address the issue of individuals or other non-state actors seeking WMD and related delivery systems. UNSCR 1540 addressed this issue, allowing UN member states to cooperate and fill a gap in their legal systems, as well as providing a requirement to enforce related effective export-control measures.[45]

Governance

UNSCR 1540 established a standing committee of experts – the 1540 Committee, created in 2004 – as well as a political and legal context for international cooperation in pursuing the goal of closing loopholes that had made it possible for non-state actors to access WMD and related delivery systems. The 1540 Committee reports to and draws its staff from the 15 UNSC members, and its work is supported by the UN's Department of Political and Peacebuilding Affairs and Office for Disarmament Affairs. The committee also has a coordinator and a group of experts (up to nine), appointed by the UN secretary-general.

Evolution

In 2010, the 1540 Committee established four working groups responsible for monitoring and national implementation, assistance to member states, cooperation with international organisations, and transparency and media outreach. In 2011, UNSCR 1977 encouraged UN member states to provide resources to the United Nations Office for Disarmament Affairs (UNODA) to help with the implementation of UNSCR 1540.[46] In 2012, the UNODA and Germany organised the first Conference of International, Regional, and Sub-Regional Industry Associations on UNSCR 1540 – the first time that the defence industry was involved in this otherwise multilateral process. In 2013, the UNODA and Austria began organising a Civil Society Forum to broaden outreach efforts to civil society.

Successes

Unlike the MTCR and the HCoC, the inclusion of export control under the UN Security Council has greater legitimacy and applicability because it involves all UN members, rather than a select few. It makes possible a broader application of dual-use export controls, as well as controls on transit, transhipment and brokering, even in the case of countries opposed to the MTCR. UNSCR 1540 therefore provides a means to apply the advances made through the MTCR, without the MTCR's disadvantages of limited legitimacy and membership. For instance, it requires all UN member states to adopt control lists – derived from the MTCR – in their national legislation in order to meet their non-proliferation commitments.[47] In addition, UNSCR 1540 has a permanent body dedicated to implementation, as well as expert and institutional support from the UN, ensuring broad participation and knowledge across the UN membership.

Weaknesses

While UNSCR 1540 has advantages over the MTCR and the HCoC, it also has several relative weaknesses, especially compared to the former. These include its limited scope; a lack of definitions and timelines for implementation, or related verification or enforcement; and a lack of responsiveness to new technologies and other developments in the field. Also, it does not specify how its requirements should be implemented. While the UNSC could in theory punish non-compliance, the lack of implementation timelines and also the UNSC's own internal divisions mean it is unlikely to do so. And as with the MTCR and the HCoC, UNSCR 1540's focus on WMD-related missiles is increasingly irrelevant to the proliferation of conventional missiles. Finally, the fact that

SECURITY COUNCIL
Divisions within the UNSC limit its effectiveness. CREDIT: Pacific Press/LightRocket by Getty Images

non-state actors are increasingly accessing and using ballistic and cruise missiles – especially in the Middle East – calls into question UNSCR 1540's effectiveness and the likelihood of recognition of the norms it was supposed to establish.

Other shortcomings of the three regimes

There are also various threats to the global governance of missiles that affect the viability and effectiveness of the MTCR, the HCoC and UNSCR 1540. These include the overlap between SLVs and offensive missile capabilities; the accelerating spread of related technologies and manufacturing processes; the return of great-power competition, with its deleterious impact on multilateral processes (especially in the UNSC); and the increasing and unchecked violence of regional conflicts.

There is a link between the proliferation of dual-capable ballistic and non-ballistic unmanned delivery systems and the spread of SLVs and commercial satellite technology. The capabilities necessary to build advanced missiles or SLVs – such as solid fuel, advanced rocket motors, satellite and internal guidance systems, computer modelling and design, and advanced composite materials for re-entry vehicles – were once possessed only by the US and the Soviet Union, but now they are accessible to private firms, certain terrorist groups, and almost any state prepared to pay the economic and political price of building or acquiring them.[48] Advances in precision, driven by developments in remote and internal guidance and avionics, are increasingly allowing UAVs to achieve capabilities commensurate with manned vehicles. The increasing availability of turbojet and turbofan technology plays an important role in endurance, allowing UAVs and aerial munitions to loiter for long periods, further complicating defence and delivering strategic effects.[49]

Finally, the return of great-power politics, resurgent nationalism, and the collapse of consensus and indeed confidence in collective security and multilateralism have caused severe damage to the global arms-control, disarmament and non-proliferation architecture. The UNSC will remain divided for the foreseeable future as an increasing number of states seek to maximise individual rather than global security, thereby accelerating arms races across Eurasia, East Asia, the Middle East and South Asia. Ongoing and recent conflicts such as Russia's war against Ukraine show the utility of ballistic and cruise missiles, as well as that of UAVs. Every domain now faces the introduction of disruptive technologies, including direct-ascent anti-satellite missiles, uninhabited surface and underwater vehicles, air-launched ballistic missiles, hypersonic cruise missiles and HGVs. When observing modern warfare, the focus of multilateral arms control measures on missiles and UAVs that can deliver WMD as a primary security concern now seems quaint.

The Way Ahead

Looking forward, there is a clear need to reform the global framework for limiting the spread of missiles and armed UAVs. Each of the three main existing regimes – the MTCR, the HCoC and UNSCR 1540 – has strengths and weaknesses, and much can be done to improve them. Implementation, verification and enforcement should be at the heart of efforts moving forward, alongside trying to ensure the transparency of internal processes and deliberations. Even without comprehensive reform, extensive political will is required to keep these agreements up to date with the pace of technological change, and much greater attention will be needed to ensure the involvement of, and cooperation with, the private sector, academia and advanced research organisations.[50] A previous paper drafted for the Missile Dialogue Initiative (MDI) outlines extensive recommendations for incremental and radical reform.[51]

These efforts must also be synchronised with the governance of outer space, including existing agreements on transparency and other CBMs, as well as the effort to regulate behaviours in outer space. Finally, reform must include more systemic engagement with other global and regional initiatives, such as the MDI and the Warsaw Process Missile Proliferation Working Group.[52] Moving forward, armed UAVs will require special attention, especially with the wide range of types and capabilities that have been mainstreamed in combat around the world. Payloads and ranges will have to be re-examined in light of the widespread use of highly precise, conventionally armed missiles and the increasingly tenuous links between missile programmes and WMD. Non-ballistic and novel trajectories should also be considered, so as to close the loophole created by the focus on ballistic and cruise missiles.

Finally, the three main regimes need to be synchronised, or perhaps even combined, under a UN mandate, with a professional international staff to serve as a permanent secretariat and dedicated institutional support to increase the reach and legitimacy of global missile controls. This process could be initiated by a resolution from the UNGA to create a Government Group of Experts (GGE) to manage a process for change, with the participation of UN member states. The most recent GGE on missiles was organised in 2008 when the situation regarding proliferation was much less complex than it is today. The significant horizontal and vertical proliferation of ballistic and cruise missiles between 2008 and 2022 therefore necessitates further attention.[53] Such a process should include a full description of the scale and scope of the problem, the types of systems and technologies to be controlled, the governance mechanism, and the steps required to make the changes. The report could recommend that the UNGA vote to convene an Open-ended Working Group to agree to a new governance mechanism and implement any such reforms, with full participation open to all UN member states.

Notes

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Conclusion:
From Cruise Control to Out of Control

This dossier has argued that conventionally armed ballistic missiles and land-attack cruise missiles (LACMs), as well as uninhabited aerial vehicles (UAVs), have an obvious attraction for armed forces. They provide operators with the capacity to attack fixed and moving targets at range, while reducing the threat to launch platforms and personnel. Highly accurate cruise missiles have transitioned from being the sole preserve of the United States some 30 years ago to being part of the inventories of around 30 countries and at least one non-state actor (NSA). This figure is certain to grow. Although the number of states possessing ballistic missiles is smaller today than it was 30 years ago, many of those states are generally operating an increasing number of different types of systems. More countries are also developing so-called novel systems, such as hypersonic boost-glide vehicles (HGVs) and direct-attack munitions, which do not fit easily within older definitions, at both the higher and lower ends of the capability spectrum. And more countries are seeking to adopt some of the lessons learned from recent conflicts – such as the Syrian civil war, the 2020 Nagorno-Karabakh war and Russia's war of aggression in Ukraine – and to acquire both high- and low-end stand-off weapons in increasing numbers and diverse configurations.

From an arms- and export-control perspective, the primary mechanisms for attempting to limit the spread of these systems have been the Hague Code of Conduct (HCoC), the Missile Technology Control Regime (MTCR) and United Nations Security Council Resolution (UNSCR) 1540. To date, they have neither completely succeeded nor completely failed. The focus within all three mechanisms on weapons of mass destruction (WMD) – whether explicitly or by defining the payload and range ceiling (e.g., the MTCR's 300-kilometre, 500-kilogram Category I threshold) – has helped to contain the acquisition of longer-range ballistic- and cruise-missile systems. More broadly, the regimes have also slowed the development of higher capabilities within some states' missile-development programmes, as has been covered in this dossier. The accelerating spread of guided-weapons technology and the demonstrated utility of these systems in conflicts, however, are further accelerating pre-existing challenges and driving proliferation. The dual capability of many of these systems – the fact that they can be equipped with and deliver either nuclear or conventional payloads

– adds to conflict-escalation risks, as the ambiguity of a missile's payload could lead a targeted country to assume the worst and pre-emptively escalate their retaliation to the nuclear level. In addition, the focus of bilateral and global arms- and export-control agreements on ballistic and cruise missiles has meant that an increasing number of states have sought systems with non-traditional trajectories, including HGVs and loitering munitions, in addition to uninhabited underwater vehicles.

It is unlikely, given the high economic costs and technical demands, that very-high-speed cruise missiles will be adopted as widely as subsonic LACMs or other, similar lower-capability systems, or at the same pace. This observation, however, is only reassuring in part. As discussed in several sections of this dossier, key cruise-missile-producing states are nonetheless pushing ahead with hypersonic cruise-missile programmes. All of the nuclear-weapon states have Mach 5+ cruise-missile projects under way and other states are likely to follow in developing this class of weapon themselves or procuring them from allies and partners. Again, the military utility of being able to deliver an effect more rapidly to the target, whilst also making it more difficult for the defender to intercept the missile, is clear. What is not clear, however, is how to solve the problem of payload ambiguity coupled with reduced reaction times.

If the very-high-speed precision-strike classes of weapons represent one vector of development, there is also activity and growing adoption at the slower end of the speed regime. The Iranian 351/*Quds* family of LACMs is notable for having been supplied and used successfully by an NSA and is an illustrative example. Iran's *Quds* is likely to be slower than many other types of LACM and it also lacks a sophisticated terminal-guidance system. What it does have in its favour is its comparative simplicity, low cost and modularity. It has been supplied by Iran to Ansarullah through illicit land and sea routes piece by piece, easing transportation and making it more difficult to detect and intercept. The missile's lack of terminal guidance, while limiting the target set it can be used against, also reduces its complexity and cost. Satellite navigation is sufficient where very high accuracy is not a concern.

Iran has been at the forefront of developing and exporting a hybrid class of weapon that has some of the attributes of an LACM but is even simpler and cheaper than the *Quds*. The *Shahed* 136 direct-attack munition, sometimes described as a 'one-way UAV' or a 'kamikaze drone', has a stand-off range greater than many LACMs and short-range ballistic missiles, albeit with a much slower speed and a lighter warhead. In the case of the *Shahed* 136, its speed is estimated at around 200 km/hour and its warhead is estimated to weigh less than 40 kg. These systems represent a significant challenge to arms-control mechanisms, as they represent a crossover between a UAV and a cruise missile. Acquired by Russia from Iran for use in its war on Ukraine, for instance, the *Shahed* 136 (or *Geran* 2, as it is known in Russian service) has proved to be comparatively easy for Ukrainian forces to intercept, but its low cost allows Russia to buy it in volume and use en masse, depleting Ukraine's more expensive and limited number of air and missile defences.

The *Quds* and *Shahed* series are emblematic of a growing concern among policymakers about the development of new types of ballistic and cruise missiles, as well as certain types of UAVs that states and NSAs are seeking. Despite their lower capabilities, low-cost and easy-to-manufacture systems could, if used in large numbers, stress a defender's capacity to deal with an attack if its air and missile defences are costly or limited in scale. These cheap systems can also be used to clutter radar systems and swarm attack vectors omnidirectionally.

The Houthis' successful use of the 351/*Quds* and the export of various *Shahed* models by Iran to Russia may well mark a further proliferation path that should not be overlooked. These types of system probably represent one aspect of future warfare, particularly in conflicts between less technologically advanced states. But the proliferation of these systems from a less-developed country – Iran – to a technologically advanced one – Russia – was unforeseen and has not yet been addressed by arms and export controls.

Considering this development, governance structures must account for both the highest- and lowest-capability systems. The MTCR, the HCoC and UNSCR 1540 have done an admirable job of creating a barrier to the proliferation of traditional and mid- to high-range WMD-related ballistic and cruise missiles. They will also probably impede the development by some states of very-high-speed technologies such as HGVs. But, as this dossier has demonstrated, these mechanisms are inadequate to halt the proliferation of lower-end technologies that are designed primarily from dual-use components. This problem is only likely to get worse as categories and definitions become increasingly blurred, complicating the efforts of existing regimes to limit systems that cross definitional boundaries. The cascading end point of these broader technological trends is clear: technologically advanced states will develop new and innovative technologies that can deliver payloads further, faster, more accurately and with a higher chance of survival for the equipment. Less developed adversaries and competitors are then likely to use the proof of concept to create competing systems that will imitate or adapt these technologies, possibly with lower-cost and more readily available components. Finally, the least-developed states and NSAs will adapt these technologies to their own capability sets and manufacture and field them for use against peer competitors and higher-end adversaries, seeking decisive advantage. This dynamic – innovation, adaptation, cost saving and mass manufacture – is likely to disrupt traditional definitions in conflict and within arms-and-export-control frameworks.

This new cycle is a case of the prisoner's dilemma, wherein opponents are locked in a competition to produce ever more sophisticated offensive and defensive systems, resulting in ruinous arms racing and unstable, escalation-prone relations. This dilemma is a classic of Cold War theory and was used to describe the nuclear arms race between the Soviet Union and the United States, as well as how two parties can use direct communication – in this case, risk-reduction mechanisms and arms control – as a means to escape a catastrophic nuclear war. However, in this post-Cold War dynamic which we might call the 'technologist's dilemma', there are many more competitors who are engaged in an increasingly rapid process of technological development, imitation and adaptation. This will require the creation of new frameworks that will be much more complex in terms of subscribers and scope than those that were established during the Cold War. Despite the difficulty of this challenge, it is vital that today's policymakers confront this issue with the same sense of vigour and purpose as their Cold War predecessors to avoid a similar outcome.

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MISSILE TECHNOLOGY: ACCELERATING CHALLENGES

The IISS Strategic Dossier *Missile Technology: Accelerating Challenges* examines the drivers, scope and consequences of the continuing development of ballistic and cruise missiles by the world's most prominent users and producers. It reviews historical, current and future development and procurement programmes and their impact on regional and strategic stability, as well as bilateral and multilateral arms-control processes that are designed to restrain proliferation. It also considers the trajectory of future technological developments, particularly Mach 5+ systems.

Missile Technology: Accelerating Challenges has a particular focus on the missile forces of China, Russia and the United States, given the quantitative and qualitative dimensions of each of these states' nuclear- and conventional-missile arsenals. It also considers other prominent producers and operators of ballistic and cruise missiles in Asia, Europe and the Middle East.

The dossier examines the opportunities and prospects for adapting arms-control mechanisms in an increasingly competitive environment, particularly within a Russia–US context. It also identifies the strengths and weaknesses of existing arms- and export-control mechanisms and confidence-building measures, and how to potentially reform these at a time when proliferation is accelerating and global security is deteriorating.

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