

Artillery in Present and Future High-Intensity Operations

edited by Elio Calcagno and Alessandro Marrone

ABSTRACT

The Ukraine war has highlighted among NATO allies the importance of planning for protracted, large-scale, and high-intensity conflicts. In this context, artillery capabilities have regained significance, with a clear emphasis on survivability, quality, quantity, range, but also on adequate munition stocks and production capacity. However, successful integration into a wider array of capabilities (including long range precision fires) and advanced Intelligence Surveillance Target Acquisition and Reconnaissance (ISTAR) capabilities are crucial for an effective artillery force. Meanwhile, in the maritime domain, recent events in the Red Sea have shown how naval artillery is gaining a prominent role as a cost-effective solution to defence from drone and swarming threats.

*Artillery | Ukraine | Russia | USA | France | UK | Italy | Procurement |
Military industry*

keywords

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This study has been realised with the support of Leonardo, and it has been completed on 10 July 2024.

Executive summary

Artillery in land warfare, between doctrine and practice

The status of artillery capabilities in NATO militaries, particularly European ones, has been deeply influenced, and in many ways hindered, by the protracted absence of an immediate threat of conflict with a peer-level adversary, at least until the Russian occupation of Crimea. Indeed, for decades since the end of the Cold War, most Western armed forces have focused their planning on expeditionary deployments such as counterinsurgency (COIN), counter-terrorism, crisis management, peacekeeping and stability operations against technically inferior adversaries, where air supremacy was almost always a given where artillery could not reach. In fact, such was the level of air dominance achieved, that in many cases artillery was not even deployed.

On the modern battlefield, the ability to effectively deliver artillery-based firepower in offensive and defensive operations alike is of the utmost importance. In such a context, "traditional", barrelled artillery such as field guns, howitzers and mortars play a massive role, as demonstrated in the Ukraine conflict. Yet this instrument cannot fulfil its true potential without being inserted into a wider array of capabilities which includes longer range systems generally known as long-range fires (LRF). Such systems, which can include longer-range guided rockets as well as cruise and ballistic missiles, can have a significant advantage relative to traditional artillery weapons in terms of range and precision. While LRFs should not be seen as merely a more advanced solution to the same requirements that are set for gun artillery capabilities, they add a crucial layer to an army's fire potential and work best in concert with solid artillery capabilities.

Furthermore, the progress made recently in the field of guided artillery shells can greatly enhance the effect's precision through a relatively simple system that is not as demanding as its guided missile or rocket counterparts in terms of training and technical know-how. Western doctrine favours precision over a high volume of fires. This approach requires solid kill-chains that rely on a variety of Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) tools including intelligence, counter-battery radars, satellite imagery, aircraft, drones and specialised ground-based teams.

The war in Ukraine has demonstrated how unprepared Western countries are with regard to increasing shell production. Shells are nevertheless only the most visible side to this issue. Gun barrels suffer from deterioration and can only fire a limited number of shots before they must be replaced. It is clear then that for a credible conventional deterrence against the threat of prolonged, high-intensity conflict against peers, industries must be put in the position to not only produce enough shells, but also to feed armies with a steady supply of gun barrels to avoid that batteries on the field are forced to ration their output as is the case for Ukrainian

forces. Such a challenge is far from trivial, requiring as it does a reliable supply of good quality, reasonably priced steel and other materials such as explosives and propellants, after decades of steep downsizing of production in Europe due to low demand.

The role of artillery in the Ukraine war

To date, the use of artillery in the Ukraine conflict has been characterised by the transparency of the battlefield and the massive consumption of ammunition. The former refers to the proliferation of systems for ISTAR missions, especially uncrewed aerial systems (UAS) which, due to their relatively low-cost per unit, represent an attritable and particularly cost-effective system to detect the presence of the enemy, direct artillery fire and assess its effects. To a significant extent, armed aerial drones are also effectively doubling up as a gap filler due to shell shortages. First-person view (FPV) drones have been particularly successful in this role, while Russia is also using cheap lethal drones at a massive scale to “augment” artillery’s effects on the battlefield.

The spread of these technologies, together with satellite imagery and signal intelligence (SIGINT) systems – applied in particular to the electromagnetic spectrum – makes it particularly difficult to conceal any force concentration and exposes troops and systems in the field to an increased risk of being detected and engaged by the enemy. This makes force concentrations, generally deemed prerogative for effective manoeuvres, particularly vulnerable.

Thanks also to large shipments from North Korea and greater domestic production levels, Russia has been able to consistently outfire Ukrainian artillery up to a ratio of over five-to-one and even ten-to-one while US military aid was suspended. Meanwhile, Western countries have so far proven unable to provide enough shells to the Ukrainians with little prospects for sustainable and long-term change as far as this trend is concerned.

Despite the shortage problem, both Ukraine and Russia have found themselves relying considerably on artillery on account of its effectiveness at its traditional uses: counter-battery fire, striking high-value targets (HVT), breaking up force concentrations, and fire support for manoeuvre warfare.

Both sides have adapted their use of artillery to ensure a higher level of survivability of their systems and, especially in the case of Ukraine, to optimise the consumption of ammunition. Since the beginning of the invasion, as a testament to their vulnerability to Ukrainian efforts, Russian artillery units have significantly increased separation from the front line, reducing this distance when there is an immediate need to conduct fire operations at closer range, only to quickly withdraw afterwards.

The necessity to improve the level of precision also with conventional artillery has resulted in faster kill-chains. For instance, Russian forces have developed a combination of detection systems, UAVs and radars, to spot enemy artillery more

efficiently, using a decoy target to push it into firing and revealing its position before responding with counter-battery. This tactic can make the timing of the sensor-to-shooter chain collapse from around 30 minutes to nearly 3 minutes. This implies that artillery batteries on both sides need to move immediately after firing to avoid counter-battery fire, therefore making mobility a fundamental aspect and indeed discouraging concentrations of forces that might make movement less fast and fluid.

A critical aspect of the use of artillery by Ukrainian forces is the high level of heterogeneity among the available systems due to foreign supplies along with the preexisting coexistence of NATO-standard and Soviet-legacy systems. This has required a considerable capacity to adapt by Ukraine due to the lack of spare parts, specific tools and know-how to maintain such a different array of systems.

The absence of air dominance situations in the conflict has increased the relevance of LRF as a vital instrument to hit in-depth enemy targets. Indeed, long-range precision-guided fires with ranges of hundreds, if not thousands, of kilometres have allowed both sides to strike HVTs deep behind enemy lines.

Land and naval artillery in the United States

The US military largely deemphasised artillery in the first few decades after the Cold War. Defence officials expected that ground wars in Europe were unlikely following the Soviet Union's fall and European allies could address the remaining threat from Russia without substantial US assistance. Although China emerged as a potential peer competitor by the 2010s, US military leaders surmised the maritime nature of the Indo-Pacific theatre and the vast distances involved would demand long-range missiles, rather than artillery.

Nevertheless, the war in Ukraine highlights the continued importance of rocket and gun artillery to gain and hold ground when air superiority is fleeting, or infeasible and electronic warfare (EW) degrades the accuracy of long-range missiles. Air defence artillery is also making a comeback as drones become a more prevalent element of air attacks from Ukraine to the Red Sea.

These trends are leading the US military to reexamine its existing gun and rocket artillery portfolio. In most cases, Department of Defence leaders are prioritising different ammunition, rather than new launchers, given the growing size and diversity of demands on the US force and emerging defence budget constraints.

Given their need to project troops, equipment, and supplies over transoceanic distances, US commanders prefer to dismantle enemy communications, sensors, and air ADs at long-range and quickly manoeuvre to objectives rather than outlast an opponent in a close-quarters artillery duel. Rockets and missiles therefore receive the lion's share of Pentagon artillery spending.

The emerging UAS threat may change this emphasis. Inexpensive and easy to build, drones can support sustained attacks at scale and deplete expensive surface-

to-air interceptors, as Ukrainian and US forces are experiencing from Europe to the Middle East. The US military is responding to this challenge by returning to cannon-based AD, but with the added precision of guided rounds. The increased investment in artillery technology could bring cannon back into favour and yield innovative solutions to Global Positioning System (GPS) jamming and spoofing.

Land artillery in France and the UK

The tube artillery systems being procured by the UK and France are designed for general support, conducting deep and precise strikes against HVTs. They are not built for prolonged close support in a war requiring extended offensive and defensive operations. The systems in question, Archer and Caesar, are more than adequate for a counterinsurgency conflict where the significant firepower delivered by all arms is focused throughout an opponent's depth. They are even suitable for a peer war in which both sides are relatively mobile, and combat consists primarily of meeting engagements. Yet the potential deficiency of these systems would be exposed in any prolonged, high-intensity engagement that requires multiple fire missions in short succession. The British and French armies are therefore in the process of replenishing their tube artillery parks after significant donations were made to Ukraine.

The on-road capabilities of Archer and Caesar are valuable for the majority of work the guns will do in their service lives, but tyres are vulnerable to shell fragmentation whereas tracks are less so. Tracks, in theory, have better off-road mobility, especially when the terrain has been damaged by the previous passage of other heavy vehicles like tanks. In short, the ideal close support system is tracked, well-armoured, and has a deep magazine.

Overall, the magazine depth, range, and mobility of both systems suggests that they are optimised to provide general support. If they are the only system capable of providing close support, the French and British militaries will have to carefully consider gun usage and resupply. It will not be possible for the systems to conduct extended and intensive fire missions without frequent resupply, which increases risk to the guns, their crews, and the vehicles resupplying them as they will eventually revisit the same sites within a battlespace again and again. Not to mention the knock-on effects that shallow magazines and the resultant gun downtime brought about by more frequent reloads will have upon the frontline troops they are meant to be supporting.

This may not matter if, in the event of a war against a peer opponent, the British and French forces are able to conduct a mobile war that relies upon unhinging an opponent with deep strikes and meeting battles. This could limit the length of engagements and consequently the amount of ammunition spent per fire mission. However, both forces would have to carefully position ammunition stocks to replenish the smaller magazines of the guns and pay close attention to expenditure rates to maximise the amount of time that their guns are available to contribute to the fight. Even then, the appearance of an enemy concentration may prove

disastrous if there are not enough guns or ready rounds to conduct a considerable and decisive engagement.

Land artillery in Italy

Like virtually all NATO counterparts, the Italian Army (*Esercito Italiano* – EI) spent the better part of the last three decades planning for and adapting its capabilities to stabilisation, COIN, counter-terrorism, training and peacekeeping operations, such as in Afghanistan, Iraq, Lebanon, Kosovo or Africa. Following the Russian full-scale invasion of Ukraine, the EI's approach to artillery has been undergoing substantial developments in terms of doctrine and operational requirements, which has exposed a number of significant capability gaps that must be filled quickly, together with longstanding shortcomings resulting from massive budget cuts following the end of the Cold War and organisational changes. Yet this process must contend with barely-increasing defence expenditure (in spite of NATO commitments) and a multitude of concurrent critical capability gaps across the Italian military.

The Ukraine war has highlighted the value of artillery systems that can deploy quickly, rapidly fire a high volume of shells, and immediately move back to safety or to new firing position in order to evade counter-battery fire. Italy's PzH 2000s thus constitute a crucial capability for the army in that they offer all aforementioned qualities with the added advantage of being able to fire Vulcano long-range unguided (Ballistic Extended Range – BER) and precision-GLR shells with ranges of up to 50 and 80 km respectively.

Two concept papers published by the EI after February 2022, in particular, define the Italian approach to artillery and how it intends to face current challenges: 2022's *Esercito 4.0* (Army 4.0) and *La manovra a contatto e le capacità abilitanti* (Deep Battle Manoeuvre and Enabling Capabilities). Army 4.0 approaches the EI's necessary evolution in terms of manoeuvre from a broad perspective, encompassing different domains and highlighting the capabilities needed to achieve it. The document also identifies a number of capabilities that must be acquired or enhanced for the EI to move in the right direction.

The Italian industry's position as a competitive player in the wider artillery market is largely ensured by the early investments made in the Vulcano munitions which still puts Leonardo ahead of competitors in the same segment both in terms of accuracy and range.

The Italian Army is at a crossroads regarding how to replace its existing howitzer systems. In this context, Italy's focus seems largely turned toward self-propelled systems specialised in shoot-and-scoot tactics, with a likely focus on self-propelled howitzers.

Naval artillery in the Italian and European navies

Naval artillery differs deeply from land artillery for technical and operational reasons. Traditional naval artillery is designed to fire conventional rounds from

a moving platform, as is the ship, at a target that is generally also moving (usually another ship or an aircraft), within or beyond line-of-sight. On the contrary, land artillery shoots from stationary positions at targets that are also generally stationary and mostly non-line-of-sight. Naval artillery systems are usually more sophisticated and versatile than land artillery because they are designed at all levels for greater precision, both in terms of the gun barrels themselves, their turrets and indeed the dedicated fire control systems, which include radar, electro-optical or both.

Naval artillery is also commonly used in anti-aircraft – and sometimes also anti-missile – roles, on top of the standard anti-ship and Naval Surface Fire Support (NSFS), which includes shore bombardment and land strike, further highlighting its versatility.

European navies, like the majority of the world's navies – equipped with Western weaponry – employ three main naval calibres: 127mm (5-inch), 76mm (3-inch) and 57mm. Smaller calibre, 40mm or less, are of little use in NSFS, because of the limited range and payload.

The Italian navy (*Marina Militare* – MM) has great confidence in its naval artilleries, an area in which it has invested heavily and where the national industry has world-leading capabilities. The Navy has a considerable number of 76mm and 127mm guns and is traditionally keen on equipping its ships with a comparatively great number of gun systems.

Guided and extended-range ammunition such as the Vulcano significantly improves the effectiveness of naval artillery, but its limited range remains insufficient in the first stages of a peer-to-peer, high-intensity conflict. However, naval artillery is likely going to retain an important role in anti-air, anti-missile, and counter-drone roles.

Conclusions

Building on the analysis presented in this study, ten key elements are worth underlining on artillery from a European and Italian point of view:

1. The renewed relevance of artillery
2. Precision-guided fires
3. A high-low mix
4. Mobility and range equal survivability
5. An integrated fires approach
6. A fast, resilient kill-chain
7. Drones: threat and asset
8. Counter-battery fire
9. More guns, more munitions: the industrial challenge
10. Focus on training

1. Artillery in land warfare, between doctrine and practice

by Elio Calcagno

The status of artillery capabilities in NATO militaries, particularly European ones, has been deeply influenced, and in many ways hindered, by the protracted absence of an immediate threat of conflict with a peer-level adversary, at least until the Russian occupation of Crimea. Indeed, for decades since the end of the Cold War, most Western armed forces have focused their planning on expeditionary deployments such as counterinsurgency (COIN), counter-terrorism, crisis management, peacekeeping and stability operations against technically inferior adversaries, where air supremacy was almost always a given where artillery could not reach. In fact, such was the level of air dominance achieved, that in many cases artillery was not even deployed.

For instance, US and allied military presence in Iraq and Afghanistan after Operation Iraqi Freedom and Operation Enduring Freedom largely relied on numerous, scattered forward operating bases (FOBs) that enabled a greater dispersion of forces in the face of agile insurgent threats.¹ Artillery capabilities therefore were generally spread out among these FOBs and often too far from military engagements with insurgent forces to play an active role.² Nevertheless, post-Cold War operations could generally count on unchallenged air supremacy and thus the lack of artillery support was counterbalanced by the availability of close air support provided by fixed-wing and rotary aircraft.³ Indeed, the very nature of operations in Iraq and Afghanistan, characterised as it was by quick-response missions deployed directly from FOBs disseminated around the country, often outside of artillery range, made air-based assets a more flexible and versatile option in that it could cover vast distances quickly and did not require dispersed logistics.⁴ Such emphasis on this type of warfare, with a marked overreliance on close air support, has had a detrimental impact on most Western militaries' capabilities in the realm of field artillery,⁵ including the US Army.⁶

Indeed, the war in Ukraine⁷ has shown how, under certain circumstances, effective air defence capabilities can fundamentally limit the capacity of air forces to operate in the battlespace in order to support ground troops and combat operations.⁸ The

¹ John Gordon IV et al., *Army Fires Capabilities for 2025 and Beyond*, Santa Monica, RAND, 2019, <http://www.rand.org/t/RR2124>.

² Ibid.

³ Ibid.

⁴ Ibid.

⁵ Jack Watling, "The Future of Fires. Maximising the UK's Tactical and Operational Firepower", in *RUSI Occasional Papers*, November 2019, <https://rusi.org/explore-our-research/publications/occasional-papers/future-fires-maximising-uks-tactical-and-operational-firepower>.

⁶ John Gordon IV et al., *Army Fires Capabilities for 2025 and Beyond*, cit.

⁷ For more on the use of artillery in the Ukraine war see chapter 2 of this study.

⁸ Mykola Oleshchuk, Viacheslav Shamko and Artem Antonov, "Air Power in the Russian-Ukrainian

same conflict also highlights how artillery remains a fundamental instrument of land warfare in its own right, in that it remains the most efficient and flexible way for armies to disperse forces while retaining the ability to concentrate effects where they are needed the most and at a few minutes notice.⁹

1.1 A balanced artillery force

On the modern battlefield the ability to effectively deliver artillery-based firepower in offensive and defensive operations alike is of the utmost importance. In such a context, “traditional”, barrelled (or tube) artillery such as field guns, howitzers and mortars play a massive role, as demonstrated in the Ukraine conflict. Yet this instrument cannot fulfil its true potential without being inserted into a wider array of capabilities which includes longer range systems generally known as long-range fires (LRF). Such systems, which can include rockets as well cruise and ballistic missiles, can have a significant advantage relative to traditional artillery weapons in terms of range and precision. For instance, whereas the Panzerhaubitze 2000 (PzH 2000) 155mm self-propelled howitzer (in service with a number of European armies including the German and Italian ones, as well as Ukraine’s) have a range of ca. 54 km¹⁰ depending on ammunition, the Army Tactical Missile System (ATACMS) ballistic missiles can have a range of up to 300 km.¹¹ Its successor, the new Precision Strike Missile (PrSM) will have an initial range of up to 500 km, and will reportedly be developed further to reach beyond 1,000 km after Washington’s withdrawal from the Intermediate-Range Nuclear Forces Treaty (INF Treaty).¹² LRFs are a crucial instrument in land warfare as they are able to carry out a number of essential tasks on the battlefields without having to come within range of most enemy artillery: suppression of enemy fires, striking enemy high-value targets (HVT); breaking up enemy force concentrations; and providing fire support to enable manoeuvre.¹³ Therefore, they are a crucial component of land forces in both offensive and defensive operations in that they can hinder enemy manoeuvres and enable one’s own.

War: Myths and Lessons Learned”, in *The Journal of the JAPCC*, No. 35 (February 2023), p. 14-24, <https://www.japcc.org/?p=16066>.

⁹ IAI interview, 19 April 2024; this approach to land combat was famously and successfully implemented by Napoleon, whose army corps mastered the art of marching separately, covering vast areas, only to quickly converge a surprised and as a consequence disorganised enemy. See: Andrew Roberts, *Napoleon the Great*, London, Penguin Books, 2015.

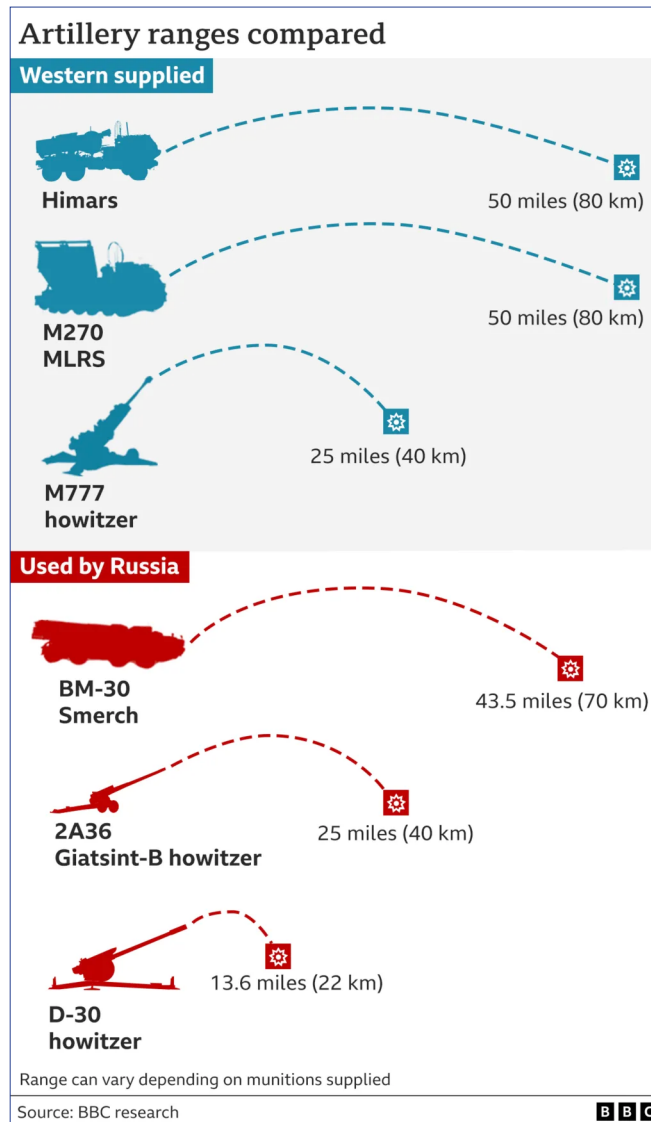
¹⁰ KNDS website: *PzH 2000*, <https://www.knds.de/en/systems-products/tracked-vehicles/artillery/pzh-2000>.

¹¹ Lockheed Martin website: *ATACMS*, <https://www.lockheedmartin.com/en-us/products/army-tactical-missile-system.html>.

¹² “Precision Strike Missile completes short-range test”, in *Australian Defence Magazine*, 22 November 2023, <https://www.australiandefence.com.au/defence/land/precision-strike-missile-completes-short-range-test>.

¹³ Jack Watling, “The Future of Fires”, cit.

Figure 1 | Ranges of artillery systems used in Ukraine



Source: "Ukraine: What Are Himars Missiles and Are They Changing the War?", in *BBC News*, 30 August 2022, <https://www.bbc.com/news/world-62512681>.

While LRFs should not be seen as merely a more advanced solution to the same requirements that are set for gun artillery capabilities, mainly due to the much higher cost of individual munitions compared to artillery shells, they add a crucial layer to an army's fire potential and work best in concert with solid artillery capabilities. This is even more crucial from a US perspective as Washington has a clear focus on the combat conditions expected in the Pacific, where the distance between fighting forces will be extremely long compared to Europe or any traditional land theatre.¹⁴

¹⁴ See in this regard chapter 3 of this study.

Advanced artillery capabilities like the PzH 2000 or similar systems, as indeed guided long-range (GLR) systems, require more complex training in order to master and deploy to their full potential.¹⁵ However, the progress made recently in the field of guided artillery shells, such as the Italian Vulcano GLR munitions, can greatly enhance the effect's precision through a relatively simple system that is not as demanding as its guided missile or rocket counterparts in terms of training and technical know-how. Furthermore, these munitions are compatible with standard guns and howitzers, meaning that they are an extremely flexible tool that can be employed by guns that are already in position without having to move the whole system, gun included.

Guided shells also present a distinct advantage in terms of logistics, in that their higher accuracy means that fewer are required to have the same effect against specific targets (unless the goal is in fact saturation of an area) and thus their deployment places a significantly lighter burden on supply lines, especially when these are dispersed.¹⁶

1.2 Fire to manoeuvre or manoeuvre to fire?

Even before February 2022, there was a stark difference in doctrinal approaches to artillery use in land warfare between Russia and NATO forces. Russian doctrine sees artillery as a central instrument for delivering effects, with its combined arms generally tasked with shaping the battlefield so that its artillery can be positioned to unleash its full potential against enemy forces.¹⁷

The Western approach on the other hand puts greater importance on manoeuvre itself, with artillery playing more of a facilitating role.¹⁸ This way of employing artillery capabilities necessarily relies on higher accuracy in order to increase the chances of hitting a specific target, while ensuring a more efficient utilisation of ammunition. Perhaps in part due to the peculiar and comparatively permissive environments experienced in post-Cold War operations, NATO forces have underestimated just how much firepower is needed to enable ground manoeuvre in a high-intensity warfare scenario against conventional forces.¹⁹

Western doctrine thus favours precision over a high volume of fires. This approach requires solid kill-chains (even multiple ones in order to ensure effectiveness

¹⁵ IAI interview, 9 April 2024.

¹⁶ IAI interview, 19 April 2024.

¹⁷ Sam Cranny-Evans, "Russia's Artillery War in Ukraine: Challenges and Innovations", in RUSI Commentaries, 9 August 2023, <https://rusi.org/explore-our-research/publications/commentary/russias-artillery-war-ukraine-challenges-and-innovations>.

¹⁸ Ibid.

¹⁹ Jack Watling, "The Future of Fires", cit.

facing enemy countermeasures)²⁰ that are in themselves relatively expensive.²¹ Unless NATO forces decide to attempt matching Russian forces in terms of artillery numbers, which seemed unlikely before the Russian invasion²² and remains so due to budgetary constraints and an enduring focus on more advanced fires, precision and efficiency will continue to play a crucial role. Yet the modern battlefield is characterised by a relatively high-degree of transparency at the tactical, operational and strategic levels thanks to advanced sensors and the proliferation of uncrewed aerial vehicles (UAVs).²³ The focus on fewer, more advanced artillery and fire systems negatively affects redundancy and thus requires an effective approach to decreasing exposure to counter-battery fires and strikes as much as possible, including by dispersing batteries and command posts, reducing electromagnetic emissions, and leveraging electronic warfare.²⁴ In this respect, LRFs comprising precision strike missiles and ballistic missiles offer NATO forces the opportunity to hit enemy HVTs while outranging enemy gun and rocket artillery which they cannot match gun- or ammunition-wise,²⁵ albeit at a much higher cost-per-munition. LRFs remain outside of the scope of this particular chapter, but they represent a crucial component in a balanced array of artillery and land-strike missiles.

Having said that, and even accounting for the specific character of the war in Ukraine, where the Ukrainians lack the air assets necessary to ensure even limited air superiority during circumscribed operations and the Russians are unwilling to risk their assets in the face of advanced enemy air defences,²⁶ artillery remains a crucial enabler for land-based military operations. Notably, the Russian approach generally relies on massed use of artillery against enemy positions through prolonged barrages saturating target areas with the aim of weakening defences or dislodging defenders, as was observed during the Russian assault on Bakhmut in 2022-2023.²⁷ This however does not mean Russian forces are incapable of delivering precise artillery fire; for instance Russian targeting cycles have been observed to take as little as three minutes between target detection and effects on the ground.²⁸ Driven by necessity due to the scarcity of artillery pieces and ammunition, but also

²⁰ Ibid.

²¹ Heather R. Penney, "Scale, Scope, Speed & Survivability: Winning the Kill Chain Competition", in *Mitchell Institute Policy Papers*, No. 40 (May 2023), <https://mitchellaerospacepower.org/?p=5174>.

²² Jack Watling, "The Future of Fires", cit.

²³ IAI interview, 25 March 2024; Alessandro Marrone (ed.), *Russia-Ukraine War's Strategic Implications*, Rome, IAI, February 2024, <https://www.iai.it/en/node/18118>.

²⁴ IAI interview, 25 March 2024.

²⁵ Jack Watling, "The Future of Fires", cit.

²⁶ Alessandro Marrone (ed.), *Russia-Ukraine War's Strategic Implications*, cit.

²⁷ Patrick Hinton, "Lean on the Barrage: The Role of Artillery in Ukraine's Counteroffensive", in *RUSI Commentaries*, 12 July 2023, <https://rusi.org/explore-our-research/publications/commentary/lean-barrage-role-artillery-ukraines-counteroffensive>.

²⁸ Mykhaylo Zabrodskyy et al., "Preliminary Lessons in Conventional Warfighting from Russia's Invasion of Ukraine: February-July 2022", in *RUSI Special Resources*, 30 November 2022, <https://www.rusi.org/explore-our-research/publications/special-resources/preliminary-lessons-conventional-warfighting-russias-invasion-ukraine-february-july-2022>.

having increasingly adopted Western doctrines since 2014, Ukrainian forces are instead prioritising accurate fire against HVTs in order to maximise results with limited means.²⁹

1.3 Re-focusing efforts

Against this backdrop, in order for artillery to be effective for NATO countries, it must be able to accurately hit enemy targets, even as they manoeuvre, and adjust targeting solutions as needed after each salvo. To this end armies have to put in place a solid kill-chain that relies on a variety of ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance) tools including intelligence, counter-battery radars, satellite imagery, aircraft, drones and specialised ground-based teams. As each of these tools has its drawbacks,³⁰ a combination of some, most or all the aforementioned instruments is preferable. Drones are an especially useful tool but have to be procured in great numbers in order to ensure persistence over enemy lines and make up for frequent losses, as demonstrated in Ukraine. Indeed, the most commonly used variants often have a very limited effect on the targets, with most videos published by both sides showing successful strikes exclusively, and therefore causing a degree of survivorship bias among observers. Most NATO armed forces are lagging behind in this field and rely largely on supply chains that are partially or completely located outside their borders, with significant implications for security of supply.

In part because of the mass employment of drones, but also due to capable counter-battery radars, artillery batteries have become more exposed and therefore vulnerable to counter-battery fire – the aforementioned transparency of the battlefield.³¹ This problem can become even more pronounced when forces that are over-reliant on artillery systems with limited range have to approach the frontline and take higher risks in order to be able to strike deeper within enemy lines, as is often the case for Ukrainian army.³² Mobility thus becomes a crucial requirement for artillery systems, allowing them to quickly move into position, accurately fire on valuable targets and rapidly re-locate in order to avoid counter-battery response – a tactic known as shoot-and-scoot. Such requirement can clash

²⁹ Serhii Baranov, "Using Artillery in Complex Environments. Lessons From The Ukrainian Front", interview with *Defence IQ*, 23 June 2023, https://eco-cdn.iqpc.com/eco/files/event_content/futart-ukraine-complex-environmentstdfinal-of-finalH1FkB0flPC3dB9cUwOvvprv9Tp8myvm12mkeWMGI.pdf.

³⁰ Intelligence work rarely leads to definitive certainty and is subject to enemy counterintelligence; counter-battery radars may not be ubiquitous on the battlefield, especially in dispersed scenarios; satellite imagery may be hindered by atmospheric weather or electronic warfare and can be updated less frequently; aircraft may be unable to access or approach enemy airspace; drones are susceptible to counter-UAS defences, and smaller commercial models vulnerable even to small arms fire, not to mention jamming which could affect the transfer of information to the operator or their ability to control the UAS; ground teams may be unable to infiltrate enemy territory and gain the necessary information and are of course vulnerable to being caught or neutralised.

³¹ Alessandro Marrone (ed.), *Russia-Ukraine War's Strategic Implications*, cit.

³² IAI interview, 22 April 2024.

with the need for extended fire range given that this is generally achieved with longer and heavier barrels, making guns more difficult to transport and deploy.

In the face of fast counter-battery fire, as in the aforementioned Russian case, artillery systems need to enable gunners to maximise effects given limited windows of opportunity. This can be achieved in a number of ways, including by maximising the speed at which rounds can be fired – by speeding up reload times – and by utilising guided munitions to land a higher proportion of shells on or near the target. Another important factor is how quickly armies are able to move batteries where they are needed the most at a particular moment and to keep them well stocked with munitions through solid and flexible supply lines. In the face of long-range fire threats that are able to reach deep within friendly lines, logistics must be dispersed enough so as not to present easy, concentrated targets to enemy action. Similarly, batteries themselves must prioritise dispersion in order to increase survivability and decrease the chance of being spotted before firing.³³

1.4 The industrial dimension

The war in Ukraine has demonstrated how unprepared Western countries are with regard to increasing shell production not just to satisfy Kyiv's need for ammunition in the face of Russian advances, but also to replenish stocks up to an acceptable level after massive post-Cold War cuts. Shells are nevertheless only the most visible side to this issue. Gun barrels suffer from deterioration and can only fire a limited number of shots before they must be replaced.³⁴ The deterioration process is inevitable, though its speed depends also on frequency and intensity of a barrel's use by its operators, meaning that when guns are over-utilised to make up for inferior numbers, frequent barrel replacements are essential.³⁵ For instance, in the US Army, gunners replace gun barrels after circa 1,500 rounds.³⁶

It is clear then that a credible conventional deterrence against the threat of prolonged, high-intensity conflict against peers, industries must be put in the position to not only produce enough shells, but also to feed armies with a steady supply of gun barrels to avoid that batteries on the field are forced to ration their output as is the case for Ukrainian forces. Such challenge is far from trivial, requiring as it does a reliable supply of good quality, reasonably priced steel and other materials such as explosives and propellants, after decades of steep downsizing of production in Europe due to low demand.³⁷

³³ IAI interview, 19 April 2024.

³⁴ Richard G. Hasenbein, *Wear and Erosion in Large Caliber Gun Barrels* (MP-AVT-109-16), June 2004, <https://apps.dtic.mil/sti/citations/ADA440980>.

³⁵ David Axe, "Russia's Artillery Is Wearing Out and Blowing Up", in *Forbes*, 25 July 2022, <https://www.forbes.com/sites/davidaxe/2022/07/25/russias-artillery-is-wearing-out-and-blowing-up>.

³⁶ *Ibid.*

³⁷ Hanna Aries, Bastian Giegerich and Tim Lawrenson, "The Guns of Europe: Defence-industrial Challenges in a Time of War", in *Survival*, Vol. 65, No. 3 (June-July 2023), p. 7-24, <https://doi.org/10.1080/00396338.2023.2218716>.

2. The role of artillery in the Ukraine war

by Nicolò Murgia¹

The ongoing Russo-Ukrainian war is providing further proof of artillery's pivotal role in a prolonged, high-intensity conflict. Artillery munitions, including rockets, both conventional and guided, have consistently been at the top of Kyiv's needs list, and their shortage has been one of the main concerns regarding Ukraine's ability to defend itself effectively. The features that have manifested on the battlefield have led to artillery's return to prominence in modern warfare, while highlighting the importance of updating tactics and doctrines in order to account for the advent of new technologies, especially in the ISTAR realm through the widespread use of armed and unarmed uncrewed aerial systems (UAS).

2.1 The main artillery-related trends in the Ukrainian war

To date, the use of artillery in the Ukraine conflict has been characterised by the transparency of the battlefield and the massive consumption of ammunition. The former refers to the proliferation of systems for ISTAR missions, especially UASs which, due to their relatively low-cost per unit, represent an attritable and particularly cost-effective system to detect the presence of the enemy, direct artillery fire and assess its effects. Furthermore, these systems, especially the simpler, off-the-shelf models, require relatively little training and are easily deployable from forward positions.² To a significant extent, armed aerial drones are also effectively doubling up as a gap filler due to shell shortages. First-person view (FPV) drones have been particularly successful in this role, while Russia is also using cheap lethal drones at a massive scale to "augment" artillery's effects on the battlefield. On the other hand, there are some drawbacks to this way of operating these systems: they require real-time operators, and the cheap, off-the-shelf drones acquired by both sides in huge numbers have limited range. The spread of these technologies, together with satellite imagery and signal intelligence (SIGINT) systems – applied in particular to the electromagnetic spectrum – makes it particularly difficult to conceal any force concentration and exposes troops and systems in the field to an increased risk of being detected and engaged by the enemy. This makes force concentrations, generally deemed prerogative for effective manoeuvres, particularly vulnerable.

In the Ukrainian context, the consumption factor refers to the difficulty of matching the rate of consumption of artillery shells with an adequate rate of production. As of the end of 2023 Ukraine was reported to be firing as many as 6,000 shells per

¹ Nicolò Murgia is junior researcher of the Defence and Security Programmes at the Istituto Affari Internazionali (IAI).

² Elio Calcagno and Alessandro Marrone (eds), "Above and Beyond: State of the Art of Uncrewed Combat Aerial Systems and Future Perspectives", in *Documenti IAI*, No. 23|24 (December 2023), <https://www.iai.it/en/node/17889>.

day, or almost half of the estimated minimum amount to carry out the needed battlefield activities.³ On the other hand, thanks also to large shipments from North Korea and greater domestic production levels, Russia has been able to consistently outfire Ukrainian artillery up to a ratio of over five-to-one and even ten-to-one while US military aid was suspended.⁴ Meanwhile, Western countries have so far proven unable to provide enough shells to the Ukrainians with little prospects for sustainable and long-term change as far as this trend is concerned.

On the battlefield, the need to limit the use of artillery ammunition (albeit to different extents for the two sides) has led to a necessary adaptation in the employment of this tool at the tactical, operational and strategic levels. Moreover, shell scarcity is somewhat exacerbated by the supply of new artillery systems and the replacement of lost ones, meaning that unitary increases in artillery pieces do not automatically lead to capacitive improvements.

Despite the shortage problem, both Ukraine and Russia have found themselves relying considerably on artillery on account of its effectiveness at its traditional uses: counter-battery fire, striking HVTs, breaking up force concentrations, and fire support for manoeuvre warfare.⁵ With non-stealth aircraft's effectiveness severely limited or outright nullified by capable Anti-Access/Area Denial (A2/AD) bubbles, the effects that artillery and LRFs can bring to bear have therefore become irreplaceable in this conflict. Indeed, while Russia's fleet of fighter jets and strategic bombers far outmatches the Ukrainian Air Force on paper, Moscow has experienced heavy losses among its more experienced pilots, with 159 of them killed since the beginning of the war as of February 2024.⁶ This has not prevented Russia from conducting airstrikes and sorties with some success, and air-launched standoff weapons are still able to hit targets deep within enemy territory. Indeed, the relatively recent addition to the Russian arsenal of increasingly effective yet cheap winged kits to convert conventional free-fall bombs into standoff weapons has had a substantial impact on the battlefield.⁷ However, without the certainty of air superiority or often even localised air supremacy, artillery continues to be a crucial tool for sustaining offensive and defensive.

³ Patrick Tucker, "The West Is Underestimating Ukraine's Artillery Needs", in *Defense One*, 22 February 2024, <https://www.defenseone.com/business/2024/02/west-underestimating-ukraines-artillery-needs/394392>.

⁴ Max Boot, "Weapons of War: The Race Between Russia and Ukraine", in *CFR Expert Briefs*, 24 April 2024, <https://www.cfr.org/node/252035>.

⁵ Harry Lye, "Why Modern Militaries Still Need Artillery", in *Global Defence Technology*, No. 119 (January 2021), https://defence.nridigital.com/global_defence_technology_jan21/why_modern_militaries_still_need_artillery.

⁶ Jack Watling and Nick Reynolds, "Russian Military Objectives and Capacity in Ukraine Through 2024", in *RUSI Commentaries*, 13 February 2024, <https://www.rusi.org/explore-our-research/publications/commentary/russian-military-objectives-and-capacity-ukraine-through-2024>.

⁷ Giorgio Di Mizio and Douglas Barrie, "Russian Glide Bombs Add Pressure on Ukraine's Diminishing Air Defences", in *Military Balance Blog*, 25 March 2024, <https://www.iiss.org/online-analysis/military-balance/2024/03/russian-glide-bombs-add-pressure-on-ukraines-diminishing-air-defences>.

The shortage of ammunition with which the Ukrainian and, to a lesser extent, Russian armed forces have had to deal has prompted both sides to introduce, not without hesitation on the part of Ukraine's Western supporters, dual-purpose improved conventional ammunition (DPICM), commonly referred to as "cluster munitions". In the Ukrainian context these munitions are usually launched by howitzers or multiple rocket launchers but can also be launched from the air. Cluster munitions disperse explosive submunitions called "bomblets" over a target area, ensuring that in order to have the desired effect on the battlefield they do not have to hit a target with pinpoint accuracy. Indeed, these shells can saturate a given area with bomblets, maximising the chance of hitting their target. The use of this type of ammunition allows the effect of artillery fire to be maximised even without maximum accuracy, also potentially reducing the number of projectiles needed to achieve the desired effect.⁸ As well as helping to manage limited ammunition stocks, this can also contribute to optimising the lifespan of gun barrels. On the Ukrainian battlefield, these characteristics have gained currency due to the factors described in this chapter.

Furthermore, in the conflict in Ukraine, Kyiv's Armed Forces have used precision-guided artillery munitions such as the Italian-made Vulcano (GLR) and US-made Excalibur. This is particularly relevant as these munitions represent an evolution of conventional artillery, through the integration of guidance systems that significantly increase their accuracy and a longer range. In the Ukrainian conflict, therefore, this type of ammunition allowed Kyiv's forces to achieve greater effects, increasing efficiency and effectiveness, from the available barrelled artillery systems. However, guided shells can be vulnerable to jamming through their GPS-based guidance system, as was observed on the battlefield with significant impact on the efficacy of Excalibur.⁹ In fact, the success rate of the Excalibur has reportedly been dropped from more than 55 per cent in January 2023 to 6 per cent in August 2023, almost nullifying the advantage of using these guided munitions over conventional ones, which are impervious to jamming. Such data demonstrates the need for guided munitions to rely on more guidance tools than just GPS and inertial navigation.

2.2 Evolution in the use of artillery on the Ukrainian battlefield

Both sides have adapted their use of artillery to ensure a higher level of survivability of their systems and, especially in the case of Ukraine, to optimise the consumption of ammunition. Since the beginning of the invasion, as a testament to their vulnerability to Ukrainian efforts, Russian artillery units have significantly increased separation from the front line, reducing this distance when there is

⁸ "Cluster Bombs: Ukraine Using Munitions 'Effectively', Says US", in *BBC News*, 20 July 2023, <https://www.bbc.com/news/world-europe-66262164>.

⁹ Isabelle Khurshudyan and Alex Horton, "Russian Jamming Leaves Some High-Tech U.S. Weapons Ineffective in Ukraine", in *The Washington Post*, 24 May 2024, <https://www.washingtonpost.com/world/2024/05/24/russia-jamming-us-weapons-ukraine>.

an immediate need to conduct fire operations at closer range, only to quickly withdraw afterwards. As reported by Ukrainian soldiers, Russian artillery batteries are located on average 12-to-15 km behind the first line, whereas Russian doctrine would require a distance of 2-to-4 km behind the defence line.¹⁰

Another relevant aspect is the increased attention to precision, even when using non-precision-guided munitions, due to their scarcity and the difficulty of amassing a high number of artillery pieces for concentrated effects over a frontline of more than 1,000 km. Force concentration is not only made difficult by the inadequate quantity of available batteries that are simply not enough to cover such a long front, but also by the risk that concentration brings by providing the enemy artillery with a target easier to locate and strike. Thus, the effects from the use of conventional artillery have been sub-optimal compared to doctrinal requirements, due to the impediments to deploying the necessary volume of fire to effectively engage enemy targets, saturating given areas and hitting enemy positions, supply lines and HVTs.

The necessity to improve the level of precision also with conventional artillery has resulted in faster kill-chains. For instance, Russian forces have developed a combination of detection systems, UAVs and radars, to spot enemy artillery more efficiently, using a decoy target to push it into firing and revealing its position before responding with counter-battery. This tactic can make the timing of the sensor-to-shooter chain collapse from around 30 minutes to nearly 3 minutes.¹¹ This implies that artillery batteries on both sides need to move immediately after firing to avoid counter-battery fire, therefore making mobility a fundamental aspect and indeed discouraging concentrations of forces that might make movement less fast and fluid.¹²

A critical aspect of the use of artillery by Ukrainian forces is the high level of heterogeneity among the available systems due to foreign supplies along with the preexisting coexistence of NATO-standard and Soviet-legacy systems. This has required a considerable capacity to adapt by Ukraine due to the lack of spare parts, specific tools and know-how to maintain such a different array of systems. The lack of proper maintenance due to wartime demands has exacerbated the issue of the consumption of the barrels, which deteriorate more quickly due to intensive use and reliance on extra firing charges to extend range but, are slower to produce than shells.¹³

The high degree of heterogeneity of artillery systems has also resulted in the employment of platforms with different levels of technological sophistication. More technologically advanced pieces, like the PzH 2000, guarantee the Ukrainian

¹⁰ Sam Cranny-Evans, "Russia's Artillery War in Ukraine", cit.

¹¹ Mykhaylo Zabrodskiy et al., "Preliminary Lessons in Conventional Warfighting", cit.

¹² IAI interview, 22 March 2024.

¹³ IAI interviews, 22 March and 9 April 2024.

army a better performance, but due to their complexity require more training to be operated. On the other side, less sophisticated systems, like the M109, for a not as high-performance can be used by troops who have received more basic training.

2.3 Drones' complementarity to artillery

Due to the complexity of hitting an isolated target with limited amounts of unguided munition without the opportunity to deploy massed fire with optimal volumes and intensity, Russian forces have increasingly relied on loitering munitions like the Lancet UAV as well as more basic FPV drones. This alternative to artillery often relies on the same ISTAR tools, for example pairing the loitering munition with a reconnaissance drone that can provide an updated information feed up to the moment of the strike. The loitering munition is directed against the target after having been stationed in the air space near its objective. This gives an edge to the force employing the loitering munitions since it is ready to strike from a close distance at the right time. At the same time however, loitering munitions are quite vulnerable in their loitering phase and therefore become "interceptable", unlike artillery shells; they also cannot return to base once deployed, meaning that they have to strike something even though a good target does not present itself.

Small-sized drones such as the ones widely used in Ukraine by both sides to carry small explosive ordnance are unable to deliver the same payload at the same range as a salvo of artillery rounds, making it an inadequate alternative to the latter though still a useful tool. The Ukrainian forces have therefore developed a tactic that integrates conventional artillery with FPV drones equipped with an explosive payload.¹⁴ Once a target has been located, a barrage of artillery fire hits the enemy forces, saturating that area. At a second stage, FPV drones are employed to target the scattered forces that survived or simply reacted to the artillery attack, with a higher level of precision. This tactic is an example of how, by integrating artillery fire with other instruments, limited numbers of shells can be employed for the destruction of a given target, compensating for ammunition shortages with a cheap and readily available system such as FPV drones. FPVs are also generally unable to achieve a real total kill against protected systems but can inflict considerable damage. Indeed, FPVs are frequently used to strike infantry fighting vehicles (IFVs) or even main battle tanks (MBTs) and take them out of action by damaging optics, electronics or affecting their mobility.

One of the main roles of drones in the Ukrainian conflict though is as an enabler for conventional artillery in ISTAR activities. The proliferation of small, cheap reconnaissance off-the-shelf drones on the battlefield led to the creation of a reconnaissance-strike-complex that improved the precision of fires even in

¹⁴ David Axe, "With Millions of Fresh Artillery Shells Arriving, the Ukrainians Are Devising New Tactics to Kill More Russians, Faster", in *Forbes*, 18 March 2024, <https://www.forbes.com/sites/davidaxe/2024/03/18/with-millions-of-fresh-artillery-shells-arriving-the-ukrainians-are-devising-new-tactics-to-kill-more-russians-faster>.

the case of conventional artillery. In this context, drones have led to substantial optimisation of the kill-chain timing.¹⁵

2.4 Precision-guided fires

The relevance of GLR fires in the conflict has been increased by the absence of air dominance, or even limited air superiority. Air power is often the designated tool to hit in-depth enemy targets, but the persistence of air defence capabilities has kept even the more sophisticated and numerically superior Russian air force from conducting air strikes deep into Ukrainian territories except when employing standoff weapons. Therefore, long-range precision-guided fires with ranges of hundreds, if not thousands, of kilometres have allowed both sides to strike HVTs deep behind enemy lines. Indeed, the supply of Western systems has allowed Kyiv to target logistical and resupply nodes, as well as strategic targets, deep behind enemy lines and with pinpoint accuracy, with significant effects on Russian operations.

The main long-range precision fire systems that were supplied to Ukraine are the wheeled High Mobility Artillery Rocket System (HIMARS), which carries one pod with six rockets and the tracked Multiple Launch Rocket System (MLRS), which carries two six-rocket pods. The munitions fired by the two launchers include the Guided Multiple Launch Rocket System (GMLRS), which has a range of more than 70 km, and the ATACMS, which carries a 227 kg blast fragmentation warhead and has a range of up to 300 km. A single pod on a HIMARS or a MLRS can host six GMLRS or one ATACMS. These launchers have provided Ukraine with a considerable advantage, as they enabled it to strike targets that were previously out of reach for conventional artillery from a much safer position well behind Ukrainian lines. At the same time, they have proven to be highly precise, survivable and mobile.

From a Ukrainian perspective, the main impact of long-range precision-guided munitions has been to force the Russian forces to stretch their supply lines and to concentrate logistic hubs, weapons depots and command and control (C2) centres further away from the first line.¹⁶ In particular, while in the initial stages of the war Russian forces could stockpile artillery munitions closer to the front, so to ensure the availability of high volumes of shells without having to implement and protect complex supply lines, the introduction of long-range precision-guided munitions has made it too risky for the Russians to concentrate large quantities of munitions within reach of Ukrainian LRFs. This resulted in more complex planning on the Russian side to ensure that shells are either out of reach or dispersed enough to increase resilience, but still readily available where and when they are necessary, with a higher level of logistical complexity.

¹⁵ Jeffrey A. Edmonds and Samuel Bendett, "Russia's Use of Uncrewed Systems in Ukraine", in *CNA Reports*, March 2023, <https://www.cna.org/reports/2023/05/russias-use-of-drones-in-ukraine>.

¹⁶ "Ukraine Rockets 'Significantly' Reducing Russian Attack Potential", in *Al Jazeera*, 15 July 2022, <https://aje.io/8bmyvy>.

However, despite some objective advantages, precision-guided munitions should not be regarded as a more efficient alternative to conventional artillery, even in the Ukrainian context, as their ideal use diverges along with their technical specifications. GMLRS and ATACMS, with a higher unitary cost and a considerably lower availability in numbers, have been used to strike targets at the strategic and operational levels. The limited stocks of HIMARS munitions have therefore been reserved for HVTs, instead of defensive positions to support manoeuvring. Unitary costs and availability have been the main obstacle to more widespread use of long-range precision-guided munitions. This has led to a stricter assessment of which targets better justify the use of such scarce resources and to a more accurate ISR effort to maximise the chances of success and avoid mistakes in locating and targeting. A relevant limitation in the use of GLR munitions in Ukraine is, as in the case of the Excalibur, the systematic use of jamming by Russian forces. Their rate of success has decreased throughout the war as the Russians have adapted their countermeasures. This highlights the vulnerability of such technologically sophisticated systems that can provide great effect but at the cost of vulnerability, a condition that does not apply to unguided conventional artillery.

In Ukraine, the use of long-range precision-guided munitions has consistently come with political implications, due to the fact that some of these systems can strike targets on Russian territory, triggering debates on the risk of further escalation fuelled by pro-Russian propaganda. The effects of this narrative are best exemplified by the reluctance of Western partners to provide long-range precision-guided munitions to the Ukrainian armed forces at the right time and in the required quantities. For instance, in October 2023 Ukraine had to pledge not to use ATACMS munitions to hit targets inside of Russia in order to ensure their provision by the US.¹⁷ Only in May 2024 did the US, along with several European countries, allow for limited strikes – only as counter-battery fire with Western-supplied long-range precision-guided munitions inside Russian territory as Ukrainian forces are under increasing pressure near Kharkiv, with the Russians hitting targets directly from Russian territory due to its proximity to the Ukrainian city.¹⁸

¹⁷ "US Decision to Send Long-Range Missiles to Kyiv a Grave Mistake – Russia's Envoy", in *Reuters*, 18 October 2023, <https://www.reuters.com/world/europe/us-decision-send-long-range-missiles-kyiv-grave-mistake-russias-envoy-2023-10-18>.

¹⁸ Matthew Lee, Amer Madhani and Zeke Miller, "Biden Partially Lifts Ban on Ukraine Using US Arms in Strikes on Russian Territory, US Officials Say", in *AP News*, 31 May 2024, <https://apnews.com/article/441c9624d95f8193e99cf08effced44f>.

3. Land and naval artillery in the United States

by Bryan Clark¹

The US military largely deemphasised artillery in the first few decades after the Cold War. Defence officials expected that ground wars in Europe were unlikely following the Soviet Union's fall and European allies could address the remaining threat from Russia without substantial US assistance. Although China emerged as a potential peer competitor by the 2010s, US military leaders surmised the maritime nature of the Indo-Pacific theatre and the vast distances involved would demand long-range missiles, rather than artillery.

The Russian invasion of Ukraine and attacks by Iranian proxies on troops and shipping across the Middle East overturned US Department of Defence (DoD) expectations regarding the utility of artillery. The war in Ukraine highlights the continued importance of rocket and gun artillery to gain and hold ground when air superiority is fleeting, or infeasible and electronic warfare (EW) degrades the accuracy long-range missiles. Air defence artillery is also making a comeback as drones become a more prevalent element of air attacks from Ukraine to the Red Sea.

These trends are leading the US military to reexamine its existing gun and rocket artillery portfolio. In most cases, DoD leaders are prioritising different ammunition, rather than new launchers, given the growing size and diversity of demands on the US force and emerging defence budget constraints.

3.1 Ground artillery

US forces would have pursued a more manoeuvre-oriented campaign against Russia compared to Ukraine, using long-range missile fires and aircraft to suppress Russian air defences to gain air superiority and protect rapidly moving ground formations. Ukrainian troops lacked the airpower and long-range fires of US forces and were compelled to fight a grinding war of inches, leading to the current stalemate. Despite the differences in speed and reach of the two approaches, US defence leaders took away the lesson that artillery capacity matters, and that US capacity may be insufficient.

3.1.1 Rocket artillery

The US Army and Marine Corps treat ground-launched missiles as part of their artillery portfolios. This stems in large part from US concepts of manoeuvre warfare, which use LRFs to attack enemy air defences, C2 nodes, and logistics hubs while close air support aircraft engage enemy troops near the front lines. This approach

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allows US mechanised ground forces to quickly move through or across enemy lines and gain positional advantage or territory without becoming entangled in protracted close combat.²

Today, US Army and Marine Corps rocket artillery consists predominantly of M30 series medium-range (about 70 km) GMLRS rockets and longer-range (about 300 km) MGM-140/-164/-168 ATACMS missiles.³ The range of ATACMS was constrained by the need to comply with the Cold War-era INF Treaty, which prohibited intermediate-range ballistic missiles of 500-to-5,500 km range. The US and Russia withdrew from the bilateral treaty in 2019, thereby terminating it.⁴ As a consequence the US Army is developing a follow-on missile to ATACMS, the PrSM, which is intended to have a range in excess of the 500 km INF Treaty limit and carry a variety of warheads.

GMLRS rockets and ATACMS missiles can be launched from the M270 Multiple Launch Rocket System (MLRS) or the newer M142 HIMARS built by Lockheed Martin. The DoD began replacing the large, tracked M270 with the smaller, wheeled HIMARS in the early 2000s to field a launcher that was usable on traditional roadways and air-transportable by C-130. Both systems carry one ATACMS missile or six GMLRS rockets per launcher pod, but while the M270 launcher includes two pods, the smaller HIMARS only has one pod.⁵

To improve their relevance for the Indo-Pacific theatre, US ground forces are pursuing an array of longer-range and anti-ship missile systems. The US Army fielded its first prototype M70 Typhon Strategic Mid-Range Fires (SMRF) system in April 2024 to the Philippines.⁶ The Lockheed Martin-built Typhon is intended to support fires at ranges between that of the HIMARS-launched PrSM and the future Long-Range Hypersonic Weapon (LRHW). The Typhon consists of a towed launcher based on the Mk-41 vertical launch system used on naval surface combatants that can carry our Navy SM-6 multi-mission missiles or Tomahawk strike missiles.⁷ As

² Amos C. Fox, "A Solution Looking for a Problem: Illuminating Misconceptions in Maneuver-Warfare Doctrine", in *ARMOR*, Vol. 129, No. 4 (Fall 2017), p. 17-26, <https://www.moore.army.mil/armor/earmor/content/issues/2017/Fall/4Fox17.pdf>; Robert R. Leonhard, *The Art of Maneuver. Maneuver Warfare Theory and Airland Battle*, Novato, Presidio Press, 1991.

³ Missile Threat, "MGM-140 Army Tactical Missile System (ATACMS)", in *Missiles of the World*, last updated on 23 April 2024, <https://missilethreat.csis.org/?p=1111>; Mark F. Cancian, "Rebuilding U.S. Inventories: Six Critical Systems", in *CSIS Commentaries*, 9 January 2023, <https://www.csis.org/node/68396>.

⁴ Daryl G. Kimball, "The Intermediate-Range Nuclear Forces (INF) Treaty at a Glance", in *ACA Factsheets*, August 2019, <https://www.armscontrol.org/factsheets/INFtreaty>.

⁵ Elisabeth Gosselin-Malo, "Lockheed Martin Preps Souped-up HIMARS Demo for Germany", in *Defense News*, 20 December 2023, <https://www.defensenews.com/global/europe/2023/12/20/lockheed-martin-preps-souped-up-himars-demo-for-germany>.

⁶ Brad Lendon, "US Sends Land-Attack Missile System to Philippines for Exercises in Apparent Message to China", in *CNN*, 22 April 2024, <https://www.cnn.com/2024/04/22/asia/us-land-attack-missile-philippines-china-intl-hnk-ml/index.html>.

⁷ US Army, *US Army's Mid-Range Capability Makes Its First Deployment in the Philippines for Salaknib 24*, 15 April 2024, <https://www.army.mil/article/275333>; Andrew Feickert, "The U.S. Army's

part of its Multi-Domain Task Forces (MDTF) in the Indo-Pacific and Europe, the Army plans to deploy HIMARS with PrSM, SMRF, and LRHWs.⁸

The US Marine Corps employs HIMARS launchers, which are normally equipped with GMLRS rockets for Marine Corps operations. However, the service is retiring HIMARS as part of its new force design, which shifts the Marine Corps' focus from short-range ground warfare to longer-range littoral operations.⁹ Instead of HIMARS, Marines units will deploy the Oshkosh Defense Remotely Operated Ground Unit for Expeditionary (ROGUE) Fires vehicle. The ROGUE vehicle is built on the Joint Light Tactical Vehicle (JLTV) chassis, which will enable it to be more easily transported than HIMARS, and rely on common logistics with the Marine Corps' other vehicles.¹⁰ It can carry two Raytheon Naval Strike Missiles (NSM) in the new Navy/Marine Expeditionary Ship Interdiction System (NEMESIS) launcher or a single Tomahawk missile in a Mk-41 launcher cell.¹¹ The trade-off between Tomahawk and NSM is the latter only has a range of about 185 km, compared to the Tomahawk's 1,600 km reach.¹²

3.1.2 Gun artillery

Despite receiving renewed attention thanks to the war in Ukraine, gun artillery continues to be deemphasised among US ground forces. US Army and Marine Corps operational concepts such as multi-domain operations (MDO) and expeditionary advance base operations (EABO) rely on long-range surface fires to suppress or defeat enemy air defences. During the resulting period of air superiority, US fixed and rotary-wing aircraft would attack enemy forces to enable ground manoeuvre.¹³ However, with ranges of 70 km or less, gun artillery is unable to engage enemy air defences without exposing US ground forces to counterattack.

Typhon Strategic Mid-Range Fires (SMRF) System", in *CRS In Focus*, No. 12135 (16 April 2024), <https://crsreports.congress.gov/product/details?prodcode=IF12135>.

⁸ Andrew Feickert, "The Army's Multi-Domain Task Force (MDTF)", in *CRS In Focus*, No. 11797 (10 July 2024), <https://crsreports.congress.gov/product/details?prodcode=IF11797>.

⁹ Irene Loewenson, "Marine HIMARS Battalion to Fold amid Overhaul of Corps Artillery", in *Marine Corps Times*, 5 March 2024, <https://www.marinecorpstimes.com/news/your-marine-corps/2024/03/05/marine-himars-battalion-to-fold-amid-overhaul-of-corps-artillery>.

¹⁰ Zach Abdi, "US Marines Conduct First NEMESIS Launch in Two Years", in *Naval News*, 19 July 2023, <https://www.navalnews.com/?p=47192>.

¹¹ Aaron Matthew-Lariosa, "Marines Activate First Tomahawk Battery", in *USNI News*, 25 July 2023, <https://news.usni.org/?p=104612>.

¹² Jaroslaw Adamowski, "Poland Buys Hundreds of Naval Strike Missiles in \$2 Billion Deal", in *Defense News*, 5 September 2023, <https://www.defensenews.com/global/europe/2023/09/05/poland-buys-hundreds-of-naval-strike-missiles-in-2-billion-deal>.

¹³ Andrew Feickert, "Defense Primer: Army Multi-Domain Operations (MDO)", in *CRS In Focus*, No. 11409 (2 January 2024), <https://crsreports.congress.gov/product/details?prodcode=IF11409>; US Marine, *Tentative Manual for Expeditionary Advanced Base Operations*, 2nd ed., May 2023, <https://www.marines.mil/Portals/1/Docs/230509-Tentative-Manual-For-Expeditionary-Advanced-Base-Operations-2nd-Edition.pdf>.

Reflecting the dependence of MDO on long-range fires, the US Army only includes rocket artillery in its newest units, the five MDTFs being deployed to Europe and the Indo-Pacific.¹⁴ Outside of MDTFs, the Army's armoured, infantry, and standard (or integrated) Brigade Combat Teams (BCT) are equipped with three main types of gun artillery: M1A2 Abrams MBT from General Dynamics Land Systems, BAE's M109 Paladin self-propelled howitzers, and towed 105mm M119 and 155mm M777 howitzers built by the US Army's Rock Island Arsenal and BAE, respectively.¹⁵

Although towed M777 and M119 artillery pieces are more numerous and easily maintained in the field, they are viewed as increasingly vulnerable and unable to support the manoeuvre needed for concepts like MDO.¹⁶ The US Army continues to upgrade the Abrams tank, including with the TROPHY Active Protection System (APS) and communication and sensing improvements as part of the M1E3 enhancement program.¹⁷ The Army is also upgrading the newest Paladin version M109A7 as part of the Extended Range Cannon Artillery (ERCA) program to incorporate a longer 30 ft (58-calibre) barrel that could allow it to engage targets at ranges up to 70 km.¹⁸ Because tests of this upgrade have been uneven, the Army is also looking at other paths to improving the M109, including the Rheinmetall 52-caliber barrel used in the BAE M109-52 prototype.¹⁹

Guided projectiles are key to the US Army's gun artillery programs. As part of their doctrinal emphasis on manoeuvre, Army units seek to efficiently engage enemy targets and reduce logistical burdens that can slow down ground forces. The Army's primary guided round, the M982 Excalibur, can achieve better than 10 m accuracy at range of more than 40 km by using an on-board inertial navigation system (INS) with GPS updates.²⁰ The Army has also been procuring precision-guidance kits (PGK) from Northrop Grumman to modify existing unguided 155mm

¹⁴ Jen Judson, "US Army Aims to Complete Multidomain Task Force Structure by FY28", in *Defense News*, 18 April 2024, <https://www.defensenews.com/land/2024/04/18/us-army-aims-to-complete-multidomain-task-force-structure-by-fy28>; Andrew Feickert, "Defense Primer", cit.

¹⁵ Jen Judson, "US Army Readies New Artillery Strategy Spurred by War in Ukraine", in *Defense News*, 1 August 2023, <https://www.defensenews.com/land/2023/08/01/us-army-readies-new-artillery-strategy-spurred-by-war-in-ukraine>.

¹⁶ Chris Panella, "US Army General Says the 'Future Is Not Bright' for Towed Artillery, Like the M777s America Gave Ukraine to Fight the Russians", in *Business Insider*, 28 March 2024, <https://www.businessinsider.in/defense/news/us-army-general-says-the-future-is-not-bright-for-towed-artillery-like-the-m777s-america-gave-ukraine-to-fight-the-russians/articleshow/108861234.cms>.

¹⁷ US DoD Director Operational Test and Evaluation (DOT&E), *FY2023 Annual Report*, January 2024, <https://www.dote.osd.mil/Annual-Reports/2023-Annual-Report>.

¹⁸ "Paladin M109A7 155mm Artillery System, USA", in *Army Technology*, 22 April 2024, <https://www.army-technology.com/?p=15225>.

¹⁹ Ashley Roque and Michael Marrow, "Shooting for the Moon: Army's 2025 Budget to Reflect Artillery Revamp", in *Breaking Defense*, 20 October 2023, <https://breakingdefense.com/?p=316794>.

²⁰ US DoD Army Financial Management & Comptroller, *Fiscal Year (FY) 2025 Budget Estimates: Procurement of W&TCV, Army*, March 2024, <https://www.asafm.army.mil/Portals/72/Documents/BudgetMaterial/2025/Base%20Budget/Procurement/Procurement-of-Weapons-and-Tracked-Combat-Vehicles.pdf>.

rounds and achieve similar accuracy.²¹

Ukrainian troops used Excalibur rounds to great effect against invading Russian forces early in the war, but in recent months Russia's GPS jamming degraded the Excalibur's accuracy to the point that the US DoD stopped sending new rounds to Ukraine.²² US Army leaders are now wrestling with how to address the vulnerability of precision weapons such as Excalibur and GMLRS rockets to GPS jamming, since incorporating more capable INS or additional sensors could make these weapons too expensive to use for volume fires.²³ Software upgrades could help by directing the weapon's guidance system to ignore GPS when it is jammed, but the likelihood of GPS spoofing – in which the munition is sent to the wrong location – could result in precision weapons providing worse performance than unguided munitions. The Army is now exploring ways to use artificial intelligence algorithms to help munition guidance systems predict their location based on a combination of environmental and guidance data when GPS is denied.²⁴

The US Army is also working on ways to use gun artillery for air defence, given the increase in drone attacks against US bases and international shipping in the Middle East and high cost of surface-to-air interceptors like the SM-2 or PAC-3. In a return to 20th Century concepts, Army units have used PGK-equipped 155mm rounds to defeat drones in combat and the US Navy is now buying PGK to upgrade 5-inch rounds for counter-UAS operations. But the more effective application of guided rounds to air defence may be with smaller guns. The Army has tested 30mm and 50mm rounds that are command-guided using a truck-mounted radar to accurately hit incoming drones.²⁵

The Army's preference for mobile artillery is reflected in its major modernisation priorities, which include only one program, Mobile Protected Firepower (MPF), that incorporates a large-calibre gun.²⁶ Designed as a replacement for the Cold War-era M551 light tank, MPF was awarded in 2022 to General Dynamics Land Systems. With lighter armour and more mobility compared to the M1A2 Abrams MBT, the MPF tank incorporates a 120mm gun like that in the M1A2.²⁷

²¹ US Army, *U.S. Army Acquisition Program Portfolio 2023-2024*, November 2023, <https://api.army.mil/e2/c/downloads/2023/11/20/0f0da2ca/2023-u-s-army-acquisition-portfolio.pdf>.

²² Cameron Manley, "The US Gave Up Sending Ukraine Excalibur Guided Artillery Shells Costing \$100,000 Because They Rarely Hit Their Target, Report Says", in *Business Insider*, 26 May 2024, <https://www.businessinsider.com/us-gave-up-sending-ukraine-100k-excalibur-shells-hit-targets-2024-5>.

²³ Ashley Roque, "Taking Aim: Army Leaders Ponder Mix of Precision Munitions vs Conventional", in *Breaking Defense*, 10 May 2024, <https://breakingdefense.com/?p=355179>.

²⁴ Inder Singh Bisht, "US Army Seeks AI-Guided Anti-Armor Artillery Round", in *The Defense Post*, 2 November 2023, <https://thedefensepost.com/?p=65704>.

²⁵ Kris Osborn, "Army Fires Off- Next-Gen Army 50mm Cannon Destroys Targets in Live-Fire Demo", in *Warrior Maven*, 6 July 2019, <https://warriormaven.com/?p=12484>.

²⁶ The modernisation priorities are: Future Vertical Lift, Next Generation Combat Vehicles, Long-range Fires, Solder Lethality, Next Generation Networking, and Contested Logistics.

²⁷ Lee F. Kitchen and Aram M. Hatfield, "Expanding Role of Mobile Protected Firepower for Army 2030", in *ARMOR*, Vol. 134, No. 4 (Fall 2022), p. 12-17, <https://www.moore.army.mil/Armor/eARMOR/>

While the US Army is keeping its gun artillery, the US Marine Corps is actively retiring cannons in favour of rocket artillery. As part of its Indo-Pacific-focused force design, the Marine Corps is reducing its number of M777 batteries from 21 to 7 by 2030.²⁸ Although it is retiring the M777, the service still plans to buy two systems in Fiscal Year (FY) 2025 to provide replacements for systems that could fail.²⁹

3.2 Naval artillery

Despite the transition of naval forces to the missile age, all US Navy surface combatants continue to incorporate gun artillery. The majority are Mk-45 5-inch/54-calibre guns, which are carried by the Navy's 74 Arleigh Burke-class guided missile destroyers (DDG) and 6 Ticonderoga-class guided missile cruisers (CG). DDGs are equipped with one gun and CGs carry two guns at fore and aft.

The Mk 45 gun has been in service since 1971 and was designed as a lighter, easier-to-maintain replacement for the Mk 42 5-inch/54 gun. Newer versions of the Mk 45 are equipped with a longer 62-caliber barrel for greater precision, although the maximum range of both the 5-inch/54 and 5-inch/62 guns is about 13 nautical miles. The Mk 45 gun is fed by a 20-round auto-loader drum underneath the gun, which allows it to achieve firing rates of up to 16-20 rounds per minute.³⁰

CGs and DDGs carry 600 rounds of 5-inch ammunition for each gun, including a mix of high-explosive and illumination rounds. With the recent rise in uncrewed system attacks against shipping and Navy warships, US surface combatants, the Navy has been reportedly testing new rounds that incorporate submunitions, which can help engage swarming small boats and airborne or surface drones.³¹

The US Navy, Army, and their industry partners have also been exploring the ability of naval and ground force guns to fire hypervelocity projectiles (HVP) that can engage missiles, drones, and other aircraft.³² BAE Systems and General Atomics Electromagnetic Systems both developed these projectiles originally to support

content/issues/2022/Fall/4Kichen-Hatfield22.pdf.

²⁸ Richard R. Burgess, "Marine Corps May Keep More Tube Artillery, Osprey Squadrons in Force Design 2030", in *Seapower Magazine*, 21 April 2022, <https://seapowermagazine.org/?p=20719>.

²⁹ US Navy Financial Management and Comptroller, *Highlights of the Department of the Navy FY 2025 Budget*, 29 February 2024, https://www.secnav.navy.mil/fmc/fmb/Documents/25pres/Highlights_Book.pdf.

³⁰ US Navy, "MK 45 - 5-inch 54/62 Caliber Guns", in *Fact Files*, last updated on 20 September 2021, <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2167864>.

³¹ Kris Osborn, "Navy Shoots Upgraded 5-inch Guns in Pacific for Live-Fire War Prep", in *Warrior Maven*, 25 November 2023, <https://warriormaven.com/?p=1061>.

³² Kris Osborn, "US Navy Could Add 'Hypervelocity Projectile' to Deck-Mounted 5-inch Guns," in *Warrior Maven*, 17 January 2024, <https://warriormaven.com/?p=891>; General Atomics, *GA-EMS Test Firings Advance Projectile Interceptor Design*, 10 March 2022, <https://www.ga.com/ga-ems-test-firings-advance-projectile-interceptor-design>.

the DoD's efforts to develop a land or ship-based electromagnetic railguns.³³ The railgun project was finally cancelled in 2021, but the railgun's ammunition may gain new life as a complement to traditional artillery shells. Instead of achieving their destructive effect using an explosive charge, the HVP rounds are designed to achieve hypersonic (greater than Mach 5) speeds when they exit the barrel and use kinetic energy alone to damage or destroy the target. Because a sabot shrouds the projectile until the gun is fired, the HVP rounds in development by both companies can be fired by 5-inch Navy (or 127mm) or 155mm Army and Marine Corps guns.³⁴ Since they travel at > Mach 5 and have ranges two or three times that of traditional gun ammunition, HVPs could enable shipboard guns, and perhaps field artillery, to be used for short-range air defence operations. However, as of yet, neither the Army nor Navy have moved these projects from research to procurement.

The Navy's Littoral Combat Ships (LCS) are equipped with a single Mk-110 57mm/38-calibre gun built by BAE Bofors of Sweden. The Mk110 is fed by an auto-loader drum with a 120-round capacity and can attain firing rates of 220-rounds per minute with a range of about 9 nautical miles. The challenge is keeping the gun fed, as the gun crew would need to change the drum out every minute to sustain firing. The LCS carries about 3 drums in the gun turret and two more drums in the magazine.³⁵

The Mk110 gun uses programmable high-explosive ammunition that allows the operator to select the fusing type (proximity or contact). To enable the Mk110 to engage fast-moving targets such as attack boats or uncrewed aircraft, the Navy contracted with Northrop Grumman in 2023 to develop guided 57mm rounds. Using an on-board seeker, the rounds – known as Advanced Low-Cost Munitions Ordnance (ALaMO) – would steer themselves into the target and detonate either on proximity or contact, depending on the type of target and geometry.³⁶

The Navy's in-development Constellation frigate program will also use the Mk110 gun. The gun will be the same as that used on the LCS, although with more ammunition carried below decks. Like the LCS, the Constellation will be able to employ the new ALaMO rounds from Northrop Grumman.

³³ BAE Systems website: *Hypervelocity Projectile*, <https://www.baesystems.com/en-us/product/hyper-velocity-projectile-hvp>.

³⁴ Ronald O'Rourke, "Navy Lasers, Railgun, and Gun-Launched Guided Projectile: Background and Issues for Congress", in *CRS Reports*, No. R44175 [Version 77] (20 October 2021), <https://crsreports.congress.gov/product/pdf/R/R44175/77>.

³⁵ US Navy, "MK 110 57 mm Gun", in *Fact Files*, last updated on 20 September 2021, <https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2167940>.

³⁶ Northrop Grumman, *Northrop Grumman to Develop New Guided Ammunition for the US Navy*, 4 October 2023, <https://news.northropgrumman.com/news/releases/northrop-grumman-to-develop-new-guided-ammunition-for-the-us-navy>.

Conclusion

With the US military's reliance on expeditionary operations and operational concepts that favour speed and manoeuvre, it is unsurprising that cannon artillery is not a high priority for the US Department of Defence. Given their need to project troops, equipment, and supplies over transoceanic distances, US commanders prefer to dismantle enemy communications, sensors, and air defences at long-range and quickly manoeuvre to objectives rather than outlast an opponent in a close-quarters artillery duel. Rockets and missiles therefore receive the lion's share of Pentagon artillery spending.

The emerging UAS threat may change this emphasis. Inexpensive and easy to build, drones can support sustained attacks at scale and deplete expensive surface-to-air interceptors, as Ukrainian and US forces are experiencing from Europe to the Middle East. The US military is responding to this challenge by returning to cannon-based air defence, but with the added precision of using guided rounds. The increased investment in artillery technology could bring cannon back into favour and yield innovative solutions to GPS jamming and spoofing.

4. Land artillery in France and the UK

by Sam Cranny-Evans¹

The tube artillery systems being procured by the UK and France are designed for general support, conducting deep and precise strikes against HVTs. They are not built for prolonged close support in a war requiring extended offensive and defensive operations. The systems in question, Archer and Caesar, are more than adequate for a counterinsurgency conflict where the significant firepower delivered by all arms is focused throughout an opponent's depth. They are even suitable for a peer war in which both sides are relatively mobile, and combat consists primarily of meeting engagements. Yet the potential deficiency of these systems would be exposed in any prolonged, high-intensity engagement that requires multiple fire missions in short succession.

4.1 The state of play of British and French land artillery

The British and French armies are in the process of replenishing their tube artillery parks after significant donations were made to Ukraine. The UK has procured 14 Archer self-propelled howitzers (SPH) from Sweden as an interim replacement for the 32 AS90s that were gifted to Ukraine, they will enter service in 2025. The Archers will be joined by the Boxer RCH 155 howitzer, which was selected under the UK's Mobile Fires Platform programme in April 2024.² The RCH 155 will be used to provide close fire support for British forces and employ the Boxer common drive module. Much of the system is to be manufactured in the UK, which was likely a key factor in its selection. France has signed for 109 Caesar Mk II SPHs that will replace the Caesar Mk I and the aging AUF1 tracked SPH from 2026. The main benefits of the Caesar Mk II are increased crew protection from small arms and explosives, and improved engine providing greater mobility, and a revised chassis. Both the Caesar Mk II and Archer are wheeled systems based on 6x6 truck chassis that provide high on-road speeds of 80 km/h and 70 km/h respectively.³ Both systems boast rapid into and out of action times of 40+ seconds for Caesar and 20 seconds for Archer, as well as firing rates of 6 rounds per minute and eight rds/min respectively. On the surface, these systems are well-matched to the conditions that are generally accepted to shape artillery operations in a modern battlespace.

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² Peter Felstead, "RCH 155 Boxer Variant Selected for British Army's Mobile Fires Platform Requirement", in *European Security & Defence*, 24 April 2024, <https://euro-sd.com/2024/04/major-news/37790>.

³ Nexter, *Caesar 6X6*, 11 May 2022, https://www.knds.fr/sites/default/files/fichiers-catalogue-produit/CAESAR_6X6_EN.pdf; UK Ministry of Defence, *British Army Announces New Artillery Deal with Sweden*, 16 March 2023, <https://www.gov.uk/government/news/british-army-announces-new-artillery-deal-with-sweden>.

For instance, the on-road mobility ensures the systems will be able to navigate and operate effectively in the urban combat that many scholars believe is already critical to modern warfare.⁴ The weight of these systems is comparatively lower than the tracked systems they replace, as shown in Table 1 below, and easier to transport strategically as they can be carried by an A400M. Although, the RCH 155 must have its drive and artillery module separated and transported in two aircraft. The ability of the systems to come into and out of action very quickly indicates they have been built to stay mobile and avoid counter-battery fire by relocating as soon as possible after unmasking. For reference, Russian counter-battery fire in Ukraine can be delivered within three minutes of Ukrainian guns unmasking, which is complicated further by tactics designed to force a gun to unmask so that it can be engaged by loitering munitions as it relocates.⁵ However, it also indicates that they are intended for fluid battlefields and frequent relocations necessitated by the movement of the units they support. As far as the rate of fire is concerned; six or eight rounds per minute essentially represents the limit of what is physically possible for large calibre systems.⁶ It might theoretically be possible to fire more rounds per minute, but cooling the barrel and ensuring the required accuracy would become problematic at best.

Table 1 | Statistics of the five artillery systems in consideration here

	AS90	AUF1	Caesar Mk I	Archer	Boxer RCH155
Running gear	Tracked	Tracked	Wheeled	Wheeled	Wheeled
On-road speed	55 km/h	60 km/h	96 km/h	70 km/h	100 km/h
Driving range	370 km	450 km	850 km	650 km	700 km
Rds/min	6	8	6	8	9
Magazine	48	42	18	21	30
Firing range	24.7 km	23 km	38.5 km	40 km	54 km
Precision munitions	N/A	Possibly BONUS	BONUS	Excalibur; BONUS	Excalibur; Vulcano; V-LAP
Strategic lift	An-124	An-124	A-400M	A-400M	A400M (two per howitzer)

Source: Sunil Nair and Mark Cazalet (eds), *Janes Land Warfare Platforms: Artillery and Air Defence, 2021/2022*, London, Janes, 2021.

Alongside new artillery systems, the UK is expanding 155mm ammunition production at BAE’s Glascoed and Washington facilities and increasing its ammunition stockpiles under the 2.4 billion pound Next Generation Munitions Solution framework agreement signed with BAE in 2021. Under the agreement, BAE will provide the British forces with a range of munitions out to 2037. A

⁴ David Kilcullen, *Out of the Mountains. The Coming Age of the Urban Guerilla*, London, Hurst, 2013.

⁵ Mykhaylo Zabrodskyi et al., “Preliminary Lessons in Conventional Warfighting”, cit.

⁶ Ajay Dubey, Pankaj Kumar Sharma, “Thermal Study of 155 mm Gun Barrel”, in *Defence Science Journal*, Vol. 72, No. 2 (March 2022), p. 172-181, <https://doi.org/10.14429/dsj.72.16625>.

190 million pound contract was signed under this agreement in 2023 that will allow an eight-fold increase in British 155mm ammunition production.⁷ French manufacturers are also increasing production to support increased demand for artillery ammunition. Eurenco, which produces nitrocellulose for propellants and energetics for ammunition explosive fill, has restarted production of the former at its Bergerac site, and has announced the intention to double its ammunition and explosives loading by 2025.⁸ Shell production in France is also set to increase. In 2022 France was able to produce around 1,000 rounds per month, which was expected to increase to 3,000 per month in 2024. The country's defence minister has also expressed the ambition to reach 4,000 or 5,000 rounds per month. All of the above is accompanied by significant expansions in industrial capacity and additional production lines, however, the maintenance of these vital capabilities will require ongoing governmental support and changes to the way that ammunition contracts have been placed in the past. Without this, there will be little financial incentive for French and British companies to maintain the production lines at the anticipated scale that has been described.

The UK is adding to its reconnaissance drone capability under the TIQUILA programme, which led to the procurement 159 Indago 4 rotary wing drones and 105 Stalker VXE30s fixed wing drones in December 2022.⁹ The Stalker provides a range of 90 km and Indago can reach around 12 km, while both are stated to be capable of target identification and passing targeting data back to effects systems. The ranges indicate that these systems will be primarily responsible for supporting the British Army's close reconnaissance needs with Watchkeeper providing deep reconnaissance at ranges in excess of 160 km out to 2042.¹⁰ France is in the process of entering the Safran Electronics & Defense Patroller fixed-wing reconnaissance drone into service, with a range of 180 km that will provide broadly similar capabilities to Watchkeeper.¹¹ Tactical capabilities include the Parrot ANAFI quadcopter with a range of 2 km, a fleet of 35 Thales Spy'Rangers provide fixed wing reconnaissance out to 30 km. Both countries will be deploying fleets of armoured reconnaissance vehicles in the form of the tracked Ajax for the UK, and the wheeled Jaguar for France.

⁷ UK Ministry of Defence Defence Equipment & Support (DE&S), *DE&S Places New Order with BAE Systems to Increase 155mm Shells Stockpile for British Army*, 11 July 2023, <https://des.mod.uk/?p=38858>.

⁸ Eurenco, *Restart of the Nitrocellulose Production on the Eurenco Bergerac Site*, 24 May 2023, <https://eurenco.com/en/?p=2475>; Eurenco, *The European Commission Awards Several Grants to Support Eurenco's Capacity Expansion under the ASAP Plan*, 22 March 2024, <https://eurenco.com/en/?p=2830>.

⁹ UK Ministry of Defence DE&S, *DE&S Orders Cutting-Edge Mini Drones for UK Armed Forces*, 16 December 2022, <https://des.mod.uk/?p=33227>.

¹⁰ Jeremy Quin, "Question for Ministry of Defence. Watchkeeper WK450", in *UK Parliament, Written Questions, Answers and Statements*, 11 July 2022, <https://questions-statements.parliament.uk/written-questions/detail/2022-07-05/31030>.

¹¹ "France to Receive Long-Awaited Patroller UAVs", in *Janes*, 4 October 2022, <https://www.janes.com/defence-news/news-detail/france-to-receive-long-awaited-patroller-uavs>.

4.2 Concepts of employment

In the UK, Ajax-equipped reconnaissance formations are included within the Deep Reconnaissance Strike Brigade Combat Team (DRS BCT), as well as the 5th Regiment Royal Artillery, which is equipped artillery-locating-radar and acoustic sensors. This provides the DRS BCT with organic reconnaissance capabilities for counter-battery effects. Reconnaissance and target location is provided in part by 32 Regiment Royal Artillery at tactical ranges, with 47 Regiment Royal Artillery operating Watchkeeper. The Patroller and Parrot ANAFI are operated by France's 61st Artillery Regiment, which is also able to receive and process satellite imagery for targeting and battle damage assessment (BDA). The 40th Artillery Regiment is equipped with Caesar, 120mm mortars, Mistral air defence systems and small drones and MURIN artillery locating radars from Thales. It is expected to provide fire support for France's Second Armoured Brigade with the 1st Artillery Regiment deploying additional counter-battery radars and MLRS.

Until the UK donated its AS90s to Ukraine, the focus for much of the Royal Artillery was on the provision of conventional close support, and it was notionally equipped to do so. For that reason, the Regiment's howitzers and rocket launchers were tracked in anticipation of supporting the UK's 3rd Division in a conventional war. They did not need to be highly mobile as they would only be deployed in association with 3rd Division and its heavy equipment, which necessitates ship-borne transport. Meanwhile the French army has always tried to strike a balance between expeditionary forces and those capable of fighting a conventional war. This has become known as the pursuit of the "medium segment". The expeditionary warfare element of the French approach has, however, dominated much of the equipment that French forces now employ. It also encourages an approach of working with what is available and does not always encourage planning. French forces also have an ethos of improvisation and making virtue out of necessity. This can be seen in Operation Serval in Mali, which was the climax of French doctrine and the very use case for which Caesars were designed. The thinking ran that it is possible to avoid the need for massed fires through precision and range, which in turn reduces logistics requirements. There is a growing awareness within the French army that this approach needs to change, but it is unlikely that a new howitzer is on the horizon, with so much of the focus at present concentrated on logistics.¹²

Both militaries are also considering the importance of the deep battle – that which is beyond the direct line of sight or conventional artillery munitions. The concept broadly holds that aggressive intelligence throughout an opponent's operational depth will reveal important targets that can be engaged with long-range artillery or rockets and lead to a destabilising effect. This was demonstrated to some extent by Ukrainian strikes against Russian ammunition dumps in 2023.¹³ The UK has

¹² Author interview with Michael Shurkin, June 2024.

¹³ Morgan Douro, "MLRS and the Totality of the Battlefield", in *RUSI Commentaries*, 21 February 2023, <https://rusi.org/explore-our-research/publications/commentary/mlrs-and-totality-battlefield>.

embraced this concept through the formation of the DRS BCT, France at present retains individual regiments and task organisation. Both are placing emphasis on the rapid transmission of data between sensors and effectors, which is important for the timely engagement of enemy forces. There are also efforts underway in both militaries to acquire additional MLRSs for their long-range artillery requirements.

It is apparent that the deep fight in Ukraine has played an important role; they have limited Russia's access to ammunition and forced it to place air defence units throughout its depth leaving some areas less protected. However, as importantly, Ukrainian strikes in the close fight have pushed Russian artillery up to 20 km behind the frontline, forcing them to come forward for fire missions before withdrawing. To do this, Ukraine of course employs a "zoo" of artillery systems including Caesar and Archer, and the UK's donated AS90s. It is trying to make the most of a difficult situation and the fighting there has a unique character that should not be expected to readily repeat itself. Nevertheless, the war has revealed the importance of close fires, especially in offensive operations against well-prepared defenders, and against offensive operations by large quantities of troops. This raises a question around the suitability of the three tube artillery systems mentioned above. All three systems are outwardly designed for a high-intensity war and capable of meeting the needs of the French and British armed forces. However, much will depend on the proportion of close to general support that these forces require to succeed in a peer conflict scenario.

4.3 General vs close support

There are two types of fire support that tube artillery can be expected to conduct: close and general support. Broadly speaking, close support is designed to defeat an opponent's fighting strength, or support manoeuvre elements as they do so. General support is designed to destabilise an opponent by destroying critical nodes within its system at range. Close support is delivered alongside effects from frontline troops such as an armoured battlegroup. The primary requirement is the delivery of sustained and accurate fire missions aimed at enemy forces in combat either in offensive or defensive operations. This means a close support system must be able to deliver enough fires onto a target within the required period of time for operational success. This might mean firing the requisite number of rounds to defeat a target very quickly, or sustained rate of fire for extended periods of time. It must also be able to occupy the same space as heavy armour in offensive operations.

General support is conducted against deeper targets like troop concentrations out of combat, command posts, ammunition dumps, or enemy guns. They are generally point targets beyond the battlegroup's typical battlespace. This requires long-range engagements and a greater reliance upon precision and speed to achieve success. It may necessitate rapidly unloading an entire battery's magazine against a single target to achieve shock and effect, or singular precision strikes against HVTs before relocating to another part of the battlespace. There is crossover between these types of targets and those that would be considered "deep", however

deep targets are mostly expected to be engaged with rocket artillery.

4.4 Magazine depth

Artillery was critical during the Second World War and used extensively by all armed forces to conduct defensive and offensive operations. Accounts from fighting in 1944 provide a valuable guide for ammunition expenditure during close support fire missions in high-intensity warfare. These figures are not definitive; however, they are indicative of what a battery may expect to spend. During the US amphibious operation to retake the Filipino island of Leyte, for example, an artillery battalion fired 75 rounds in a single engagement. The next day, the same battalion spent another 80 rounds in one engagement, followed by 150 in another later that day. Another fire mission from six batteries later in the battle consumed 240 rounds.¹⁴

If 12 of the UK's 14 Archers were responsible for the final fire mission of 240 rounds, that would equate to 20 rounds per gun. Leaving just one round per gun and requiring the system to be reloaded before it could contribute again. For Boxer RCH 155, 12 guns firing 20 rounds would be left with 10 rounds per gun, enough for one more smaller fire mission before reloading. The same number of AS90s, however, could conduct the same fire mission again using its stowed ammunition. If six batteries of Caesars (18 guns) conducted the same mission, they would consume around 13-to-14 rounds each, leaving each gun with 4-to-5 rounds. If 18 AFU1s were used, they also would have spent 13-to-14 rounds each, but each gun would have 28 rounds remaining. Clearly, the number of guns available distorts this analysis, but it should be evident that the larger a gun's magazine, the better suited it is to prolonged and extensive engagements.

It is not the case that Archer and Caesar are not designed for close support; it is simply that they were built for armies that expect to fight on the move. Consider, for example, the composition of French battlegroups during Operation Serval, which included an artillery group of two Caesars and four 120mm mortars, as well as 66 wheeled combat vehicles of various types.¹⁵ The French operations under Serval are not the only type that the army fights, but their ambitious and mobile – almost nomadic – nature shows why a wheeled system with a limited magazine depth like Caesar is necessary. The Swedish army in turn plans around a high-intensity war that requires its armoured units to creatively use the country's available space to degrade and attrit a Russian force by never presenting a significant and solid target to be engaged decisively.¹⁶ In this context, the wheeled Archer is a must.

¹⁴ William P. O'Connor, "Battle of the Tagbong River", in *The Field Artillery Journal*, Vol. 35, No. 5 (May 1945), p. 295-300.

¹⁵ Michael Shurkin, *France's War in Mali. Lessons for an Expeditionary Army*, Santa Monica, RAND, October 2014, <http://www.rand.org/t/rr770>.

¹⁶ Briefing delivered by senior Swedish armour officer at the 2024 International Armoured Vehicles conference in Twickenham.

It is expected to use Sweden's road network to rapidly navigate and provide fire support against an opponent that is reliant upon immobile command posts and ammunition dumps.

To meet these demands, which necessitate long-range fires and high on-road mobility in support of mobile units, all three guns can fire the M982 Excalibur precision munition, Caesar and Archer can fire the BONUS sensor-fused munition against armoured vehicles, with a 50 km and 35 km range respectively. The 52-calibre barrels used are also designed to provide maximal range firing conventional HE (High Explosives), which is demonstrated by Caesar firing over 13,000 rounds at charge of 5 or 6 in Iraq.¹⁷ Furthermore, Archer is capable of unloading its entire magazine in a little over three minutes, which – combined with its rapid out of action time, suggests it is designed to deploy massive firepower against a concentrated target such as a Russian form-up point, before relocating. Caesar is theoretically capable of achieving the same level of intensive fire but would need to be co-located with additional ammunition for anything requiring more than 18 rounds per gun.

4.5 Supporting an armoured assault

Manoeuvre elements by contrast require shorter range systems that can generate consistent support. An armoured battlegroup is realistically fighting over an area 1-to-5 km deep and one or two km wide. It does not need to fight against targets that are 30km+ and beyond what its organic sensors can identify. Instead, it requires artillery batteries that can conduct multiple fire missions in support of section actions without reloading. This in turn requires a gun that can hold three primary ammunition natures in sufficient quantities to support offensive or defensive actions. In this scenario, the added range of the 155mm guns is beneficial for the survivability of the gun crew as it can place them further from the frontline.¹⁸ It may also enable different batteries to come to the aid of an armoured battlegroup, but it is not an essential requirement for close support. It is also worth noting that while these guns can theoretically shoot further, this does not guarantee effect. As range of artillery fire increases, so does dispersion of the fall of shot, which can lead to an increase in ammunition consumption compared with a fire mission conducted at shorter ranges.¹⁹

The fire support itself is concerned with suppressing and obstructing an adversary, thereby preventing them from effectively countering an armoured advance. This might consist of a smoke screen on an objective designed to last for the duration of an advance or suppressive HE fires at a rate of one or two rounds per gun per

¹⁷ Olivier Fort, "Caesar: The Long-Range Proven 155mm 52 Cal", in *South Asia Defence & Strategic Review*, Vol. 16, No. 1 (March-April 2022), p. 19, <https://www.defstrat.com/?p=2815>.

¹⁸ Sam Cranny-Evans, "Russia's Artillery War in Ukraine", cit.

¹⁹ John Musgrave, *Firepower. Making 21st Century Warfare Decisive*, Salisbury, Riverside Publishing Solutions, 2020.

minute against the same. It is important for these rounds to land in the right zone, but not essential to have the 10 m CEP (Circular Error Probable) of the US-made Excalibur guided munitions. It is also important that the guns providing that fire support are well-protected from counter-battery fire and close enough to move with the armoured elements as their offensive develops. It could be argued that tracked systems meet these requirements more effectively than wheeled. The on-road capabilities of Archer and Caesar are valuable for the majority of work the guns will do in their service lives, but tyres are vulnerable to shell fragmentation whereas tracks are less so. Tracks, in theory, have better off-road mobility, especially when the terrain has been damaged by the previous passage of other heavy vehicles like tanks.²⁰ In short, the ideal close support system is tracked, well-armoured, and has a deep magazine.

4.6 Does it matter?

Overall, the magazine depth, range, and mobility of both systems suggests that they are optimised to provide general support. If they are the only system capable of providing close support, the French and British militaries will have to carefully consider gun usage and resupply. It will not be possible for the systems to conduct extended and intensive fire missions without frequent resupply, which increases risk to the guns, their crews, and the vehicles resupplying them as they will eventually revisit the same sites within a battlespace again and again. Not to mention the knock-on effects that shallow magazines and the resultant gun downtime brought about by more frequent reloads will have upon the frontline troops they are meant to be supporting.

This may not matter if, in the event of a war against a peer opponent, the British and French forces are able to conduct a mobile war that relies upon unhinging an opponent with deep strikes and meeting battles. This could limit the length of engagements and consequently the amount of ammunition spent per fire mission. However, both forces would have to carefully position ammunition stocks to replenish the smaller magazines of the guns and pay close attention to expenditure rates to maximise the amount of time that their guns are available to contribute to the fight. Even then, the appearance of an enemy concentration may prove disastrous if there are not enough guns, or ready rounds to conduct a considerable and decisive engagement.

Consider, for example, a scenario in which an armoured battlegroup achieves a limited break-through only to be confronted by an enemy battalion in defensive positions. Ideally, an extensive artillery preparation would be conducted against strong points ahead of a continued advance, which would be accompanied by

²⁰ J.Y. Wong and Wei Huang, "Wheels vs. Tracks' – A Fundamental Evaluation from the Traction Perspective", in *Journal of Terramechanics*, Vol. 43, No. 1 (January 2006), p. 27-42, DOI 10.1016/j.jterra.2004.08.003; You may also read the author's own article on the matter here: "The Role of Wheeled Vehicles in Peer Conflict and the Tracks vs Wheels Debate", in *European Security & Defence*, 30 January 2023, <https://euro-sd.com/2023/01/articles/29120>.

continued suppressing fire against anti-tank teams and counter-battery fire. Failure in any of these three missions would expose the battlegroup to potentially devastating fires. In static conflicts where reconnaissance and strike assets are likely to be very closely linked, it may become imperative for guns to move after unmasking or stay in place and withstand counter-battery strikes. Fire missions are likely to be prolonged and require occasional peaks in output. It is also likely that guns will have to mass fires to engage enemy concentrations, at which point magazine depth could become a critical and limiting factor.

Ultimately, the doctrine of these forces will decide how they fight the guns but the technology they are procuring will shape this doctrine and the ability of both forces to deliver against a peer opponent significantly.

5. Land artillery in Italy

by Elio Calcagno and Nicolò Murgia

Like virtually all NATO counterparts, the Italian Army (*Esercito Italiano* – EI) spent the better part of the last three decades planning for and adapting its capabilities to stabilisation, COIN, counter-terrorism, training and peacekeeping operations, such as in Afghanistan, Iraq, Lebanon, Kosovo or Africa.¹ Following the Russian full-scale invasion of Ukraine, the EI's approach to artillery has been undergoing substantial developments in terms of doctrine and operational requirements, which has exposed a number of significant capability gaps that must be filled quickly, together with longstanding shortcomings resulting from massive budget cuts following the end of the Cold War and organisational changes. Yet this process must contend with barely-increasing defence expenditure (in spite of NATO commitments) and a multitude of concurrent critical capability gaps across the Italian military.

5.1 Current capabilities and gaps

The EI's current artillery capabilities are spread among 10 specialised regiments and are mostly based on the PzH 2000 155mm self-propelled howitzer (67 pieces as of 2023), the OTO Melara Mod 56 105mm pack/towed howitzer (25 pieces), the FH-70 155mm towed howitzer (148 pieces), and MLRS multiple rocket launcher (21 pieces).² These numbers do not reflect current numbers, however, as Italian donations to Ukraine have involved field artillery but are still classified. The FH-70 constitutes the bulk of the army's field artillery arsenal and is the result of a cooperation programme involving the UK, Germany and Italy. The participating countries set highly ambitious requirements for this howitzer, including the presence of an Auxiliary Power Unit (APU) that allow the crew to move the gun for short distances in order to quickly redeploy during combat operations. Despite a delayed entry into service in 1978 and a number of "teething issues" the FH-70 has become a capable system and, especially thanks to its ability to some extent shoot-and-scoot, or quickly redeploy to new positions after firing without being towed by a second vehicle, a versatile howitzer even in the face of increased threats posed by faster counter-battery fire and drones. The Italian Army believes that the FH-70, despite its age, is still an adequate solution to modern battlefield requirements and has commenced a modernisation programme for 54 pieces in order to replace the APU with a New Power Pack and update the gun with a Laser Inertial Navigation Artillery Pointing System (LINAPS) and a Muzzle Velocity Radar (MVR) in order to increase tactical flexibility and improve performance also in environments where communications and satellite navigation systems are jammed.³

¹ Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, Roma, Rivista militare, 2024, <https://issuu.com/rivista.militare1/docs/suppl-2-2024-low1>.

² International Institute for Strategic Studies, *The Military Balance 2023*, 2023.

³ Aurelio Giansiracusa, "Ammodernamento degli FH-70 dell'Esercito Italiano", in *Ares Osservatorio*

The Ukraine war has highlighted the value of artillery systems that can deploy quickly, rapidly fire a high volume of shells, and immediately move back to safety or to new firing position in order to evade counter-battery fire.⁴ Italy's PzH 2000s, produced in Italy under license and presenting some changes from their German counterparts,⁵ thus constitute a crucial capability for the army in that they offer all aforementioned qualities with the added advantage of being able to fire Vulcano long-range unguided (Ballistic Extended Range – BER) and precision-GLR shells with ranges of up to 50 and 80 km respectively.⁶

The EI's deep manoeuvre capabilities are currently build around the MLRS multiple rocket launcher, which is seen as vital, with ongoing efforts to further extend its range with new ammunition.⁷ The army is updating the platforms currently in service to the M270A2 standard so that they are capable of launching Extended Range guided rockets with a range of up to 150 km (its acquisition is planned) and the PrSM, a tactical ballistic missile with a range of over 499 km (now that the INF Treaty limits no longer applies) which are mentioned albeit more vaguely.⁸ The PrSM would be a significant acquisition for the Army in that it would represent the first time since the now-retired LTV's Lance tactical ballistic missile that Italy has such a tool at its disposal.

Counter-battery radar capabilities in the Italian Army are currently deemed to be insufficient, being provided by only four Artillery Hunting Radar (ARTHUR) systems, a number more in line with the operational needs typical of stabilisation, peacekeeping and COIN operations.⁹ As the EI rethinks its posture in light of lessons identified from the conflict in Ukraine, the acquisition of more, and more advanced, counter-battery radars has become one of its main procurement priorities. Indeed, a call for proposals was published in June 2023 for the supply of 13 new counter-battery radars for a total of about 156 million euros, though the winner has not been publicly announced yet as of time of writing.¹⁰ A jump from

Difesa, 6 August 2023, <https://aresdifesa.it/?p=42694>; Leonardo Electronics, *LINAPS Artillery Pointing System* [Brochure], 2023, <https://electronics.leonardo.com/en/products/linaps>.

⁴ For more on lessons from the war in Ukraine and current trends regarding the use of artillery in high-intensity operations see chapters 1 and 2 of this study.

⁵ Tiziano Ciocchetti, "Guerra in Ucraina: le forniture italiane", in *Difesa Online*, 16 May 2022, <https://www.difesaonline.it/node/16893>.

⁶ Leonardo Electronics, *Vulcano 155*, 2021, https://electronics.leonardo.com/documents/16277707/0/Vulcano+155+%28MM08723%29_HQ.pdf.

⁷ IAI interview, 22 March 2024.

⁸ Aurelio Giansiracusa, "MLRS M270A2 per l'Esercito Italiano", in *ARES Osservatorio Difesa*, 29 April 2023, <https://aresdifesa.it/?p=40460>.

⁹ "Tredici radar controfuoco per l'Esercito Italiano", in *ARES Osservatorio Difesa*, 24 June 2022, <https://aresdifesa.it/?p=32443>.

¹⁰ Italian Ministry of Defence, *Integrazione alla determinazione a contrarre n.84 in data 17.05.2022 "EF 2022 - Fondo Composito Difesa 2021 e Fondo Difesa 2022; Acquisizione radar controfuoco - VSP 200 7120-03C 120PB 12 308-001 e 200 7120-03C 120PB 12 308-002 - Lettera di mandato n. 34/2022*, 22 May 2023, <https://www.difesa.it/assets/allegati/1580/fc14360f-4717-4e36-bfc1-af88025f965b.pdf>.

four to a total 17 radars (a combination of existing and new systems) indirectly demonstrates how big a gap the army identified in this field and how keen it must be to fill it as soon as possible.

5.2 Planning and procurement priorities

Two concept papers published by the EI after February 2022, in particular, define the Italian approach to artillery and how it intends to face current challenges: 2022's *Esercito 4.0* (Army 4.0)¹¹ and *La manovra a contatto e le capacità abilitanti* (Deep Battle Manoeuvre and Enabling Capabilities).¹²

Army 4.0 approaches the EI's necessary evolution in terms of manoeuvre from a broad perspective, encompassing different domains and highlighting the capabilities needed to achieve it.¹³ While the document rightly identifies the armoured component as a critical gap in terms of close battle manoeuvre, artillery is the main focus in terms of deep manoeuvre. Indeed, the army's main goal in this regard is to double the range at which its forces can engage and destroy enemy troops at depth, from 70 to 150 km. To achieve this the EI sets out a number of measures starting with efforts to: "integrate all systems able to deliver effects at depth (kinetic and non-kinetic) through the combined use of EW, armed and unarmed drones, and precision munitions".

Army 4.0 identifies a number of capabilities that must be acquired or enhanced for the EI to move in the right direction. Firstly, the army needs to strengthen its MLRS capabilities and supply all of its artillery units with Vulcano shells in its BER and GLR variants. The latter is an especially important endeavour as it fits into a wider push to "vulcanizzare" (vulcanise) as wide as possible an array of artillery systems and make them more precise and far-reaching instruments through the use of existing Vulcano munitions.¹⁴ Indeed, the army wishes to promote the development of precision-guided ammunition for land artillery systems beyond 155mm, evaluating the feasibility of turning a wider array of systems into precision-fire assets.

Loitering munitions and armed and unarmed drones able to carry out target acquisition, laser designation and BDA tasks represent another crucial area where the EI wants to make significant progress also in view of the dynamics observed in the Ukraine conflict. In this regard, the procurement by the EI of the first X-25 Rapier mini-UAVs with ISTAR capabilities is a step in this direction.¹⁵ The

¹¹ Italian General Staff of the Army, *Esercito 4.0*, September 2022, <https://www.esercito.difesa.it/comunicazione/editoria/Rivista-Militare/Documents/2022/Esercito%204.0.pdf>.

¹² Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, cit.

¹³ Italian General Staff of the Army, *Esercito 4.0*, cit.

¹⁴ Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, cit.

¹⁵ "Sky Eye Systems firma un contratto con l'Esercito per il suo APR Rapier X-25", in *Coccarde Tricolori*, 25 January 2023, <https://www.coccardetricolori.it/?p=3472>.

procurement of ready-to-use loitering munitions has gained particular urgency, though no requirements have been set as of time of writing.

Extending the range at which Italian artillery can engage enemy targets is a clear priority for the army and the procurement of 21 M142 HIMARS wheeled rocket launchers, as originally planned in 2023, will undoubtedly constitute a substantial strengthening of the EI's artillery potential.¹⁶ HIMARS trades some of the off-road mobility of the tracked MLRS and reduces the payload (a single rocket/missile pod instead of two) but gains a major strategic mobility advantage. With upgraded MLRS and the HIMARS the Army will double its rocket artillery force.

In terms of gun artillery, the Italian Army is currently discussing an upgrade and "full vulcanisation" of its PzH 2000, which could also include a follow-on order to replace the systems transferred to Ukraine. The Army is also looking at a new 105mm towed gun to replace the current and very old, towed M-56 in light infantry brigades. Several options are being evaluated, but no decision has been taken yet. In general, a significant effort will likely have to be made in terms of bringing the number of available field guns up to the required numbers, especially given the proven value of mass and increased vulnerability of artillery batteries to different threats.

The need to increase mobility as a precondition for survivability is well understood by the Army and this is the reason why also heavy mortars in mechanised infantry units will likely to be procured in the form of breech loaded turreted weapons to replace the traditional mortar carriers, with standard mortars muzzle loaded by the crew in an open firing compartment.

5.3 Beyond guns and platforms

5.3.1 The industrial challenge

The Italian industry's position as a competitive player in the wider artillery market is largely ensured by the early investments made in the Vulcano munitions which still puts Leonardo ahead of competitors – for Instance the French Katana by French company Nexter, which is still under development, and the US-made Excalibur (BAE Systems) – in the same segment both in terms of accuracy and range.¹⁷ However, the most modern towed howitzer currently in Italian service is the FH-70 which, despite the ongoing modernisation process, was originally designed in the 1960s.

¹⁶ "Gli USA approvano la vendita degli HIMARS all'Italia", in *Portale Difesa*, 18 Dicembre 2023, <https://www.rid.it/shownews/6222/gli-usa-approvano-la-vendita-degli-himars-all-rsquo-italia>.

¹⁷ IAI interview, 9 April; BAE Systems website: *Excalibur*, <https://www.baesystems.com/en/product/excalibur--tell-the-round-where-to-go-ndash-and-it-goes-there>; Nexter, *155 Katana*, 2022, https://www.knds.com/fileadmin/user_upload/content/Newsroom/PressAreas/2022_Eurosatory/KATANA/KATANA_Data_sheet.pdf.

The Italian Army is therefore at a crossroads regarding how to replace these systems. In this context, Italy's focus seems largely turned toward self-propelled systems specialised in shoot-and-scoot tactics,¹⁸ with a likely focus on self-propelled howitzers. The Army has developed an interest in the fully automated 155mm/L52 gun system, to be installed perhaps on a yet-to-be-selected platform. For example, Krauss-Maffei Wegmann and Rheinmetall have combined efforts to fit this gun onto a wheeled vehicle, resulting in the RCH 155, the first self-propelled howitzer able to fire while moving.¹⁹

While the PzH 2000 is a German design, Italian units were produced in Italy under licence by the IVECO-OTO Melara consortium (Consorzio IVECO-OTO Melara – CIO) meaning the industrial know-how to produce such systems at scale is present in the country. In principle, looking ahead, there may be different opportunities for Italy which may include one or a combination of the following: (i) pursuing a multinational programme in order to design 155mm self-propelled platforms to eventually replace the FH-70 and eventually the PzH 2000; (ii) to work on wheeled smaller calibres systems that are even more mobile; and/or (iii) to take the risk, as some feasibility studies are exploring,²⁰ to develop systems capable of shooting while moving in order to minimise their vulnerability to loitering munitions and counter-battery fire even further.²¹ Given the existence on the market of systems such as the aforementioned RCH 155, which is already capable of on-the-move firing, the army may opt for a national adaptation of such a system given its mobility, ease of operation (its gun unit is uncrewed and automated).

Although most of the narrative around the supply of artillery capabilities to Ukraine has revolved around artillery systems and shells, the ability for the national industrial base to have access to an adequate supply of steel and special machine tools to transform it into gun barrels remains a highly important issue, even beyond the Italian context.²² Considering the limited number of 155mm barrels produced in Italy since the end of the Cold War, an increase in production is not exactly a trivial endeavour for the industry, which has had to make substantial investments since 2022 in order to prepare for a spike in demand in terms of facilities and work force.²³ Furthermore, amid recurring donations of weaponry to Ukraine,²⁴ the army is called to invest considerably on the update of existing assets and the acquisition of new systems (such as HIMARS), as well as in the renewal of Italy's obsolete

¹⁸ IAI interviews, 22 March and 19 April 2024.

¹⁹ Robert Dougherty, "Automated Artillery Achieves World First Fire-While-Moving Capability", in *Defence Connect*, 26 September 2023, <https://www.defenceconnect.com.au/land/12856>.

²⁰ IAI interview, 25 March 2024.

²¹ IAI interviews, 22 March and 19 April 2024.

²² IAI interview, 9 April 2024.

²³ IAI interviews, 22 March and 9 April 2024.

²⁴ "Guns Not Gnocchi: Italian Military Aid to Ukraine", in *Oryx*, 22 May 2023, <https://www.oryxspioenkop.com/2023/05/guns-not-gnocchi-italian-military-aid.html>.

armoured capabilities.²⁵ Crucially, there remains at the same time an urgent need to replenish munitions stocks, which have been left to linger at minimum levels for three decades except for guided shells.²⁶ This issue inevitably turns a spotlight onto constrained production capabilities resulting from inadequate orders since the early 1990s, yet it also extends to the problem of storing a larger amount of munitions by expanding or acquiring new warehouses,²⁷ with all the consequent obstacles tied to expanding, acquiring, building, staffing and guarding such depots as well as political sensitivities.

5.3.2 A new approach to artillery

Beyond the need to acquire new platforms and munitions, the EI's "Deep Battle Manoeuvre and Enabling Capabilities" concept paper emphasises the importance of making sure future acquisitions must be interoperable with the latest platform-level C2 system, the C2DN EVO,²⁸ and the Imperio Battlespace Management system.²⁹ The EI aims for this integrated approach to the use of artillery to encompass therefore also air defence, including very short-range air defence (VSHORAD)³⁰ and counter-UAV systems, as well as the combined deployment of UAVs for engaging enemy forces, laser target designation, ISTAR and BDA tasks.³¹

Furthermore, the army is exploring ways to disperse artillery capabilities more widely in order to maximise survivability and manoeuvre speed. Dispersion requires a new approach to logistics and the EI is keen to develop a new, distributed approach to more capillary logistics in order to support artillery operations adequately and resiliently in degraded environments.³²

Beside all aforementioned priorities tied to platforms, munitions and evolving doctrine, the EI suffers greatly from the inability to properly train its artillery crews – and forces in general – in Italian firing ranges due to political and local opposition. This in turn heavily limits the range at which guns are allowed to shoot and how frequently, with obvious consequence on warfighting readiness.³³ The problem is so acute that the Army recognises it will have to rely increasingly on

²⁵ "Italy Plans to Buy Leopard 2 Tanks to Boost Ground Forces" in *Reuters*, 13 July 2023, <https://www.reuters.com/business/aerospace-defense/italy-plans-buy-leopard-2-tanks-boost-ground-forces-2023-07-13>.

²⁶ IAI interview, 17 April 2024.

²⁷ Ibid.

²⁸ Leonardo, "C2D/N EVO: The Innovative Command, Control And Navigation System for Land Forces", in *Leonardo Focus*, 11 March 2024, <https://www.leonardo.com/en/focus-detail/-/detail/sistema-di-comando-controllo-navigazione-per-forze-terrestri>.

²⁹ Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, cit.

³⁰ Ottavia Credi et al., "Short Range Air Defence: Operational and Technological Developments", in *Documenti IAI*, No. 22|07en (September 2022), <https://www.iai.it/en/node/15971>.

³¹ Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, cit.

³² Ibid.

³³ IAI interview, 19 April 2024.

foreign firing ranges such as in Kuwait.³⁴ Achieving a degree of combat readiness for the army's artillery component commensurate with the current threats and risks will require a holistic approach that cannot leave any of the aspects discussed in this chapter behind, including adequate training for the EI's personnel.

³⁴ IAI interview, 25 March 2024; Italian General Staff of the Army, *La manovra non a contatto e le capacità abilitanti*, cit.

6. Naval artillery in the Italian and European navies

by Eugenio Po¹

Naval artillery differs deeply from land artillery for technical and operational reasons. Traditional naval artillery is designed to fire conventional rounds from a moving platform, as is the ship, at a target that is generally also moving (usually another ship or an aircraft), within or beyond line-of-sight. On the contrary, land artillery shoots from stationary positions at targets that are also generally stationary and mostly non-line-of-sight. Naval artillery systems are usually more sophisticated and versatile than land artillery because they are designed at all levels for greater precision, both in terms of the gun barrels themselves, their turrets and indeed the dedicated fire control systems, which include radar, electro-optical or both.

Naval artillery is also commonly used in anti-aircraft – and sometimes also anti-missile – roles, on top of the standard anti-ship and Naval Surface Fire Support (NSFS), which includes shore bombardment and land strike, further highlighting its versatility.

Despite land strike cruise missiles such as the Tomahawk greatly outranging naval artillery, NSFS still retains a role among the tasks that are required of modern navies. In recent years, Iraq (2003) and in Libya (2011) there were examples of this deployment by the navies of Australia,² France and UK.³ On several occasions Israel also employed this instrument, including during the current conflict against Hamas.

By design, ship-based artillery is more accurate than land-based systems, because naval cannons are “dual-purpose”, in that meaning they are designed to engage both surface and air targets: this translates in a weapon system that is optimal for point target neutralisation and destruction.

Naval fire can very useful against “hardened” targets and can employ special and precision ammunition, such as the Italian Vulcano GLR.

While similar to their land-based counterparts in many respects, naval artilleries enjoy a number of comparative advantages. For instance, naval guns are fully automatic and have therefore a higher rate of fire, with greater ammunition capacity thanks to large magazines – often automated – onboard ships. Given that

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² Mark Anderson, “HMS Marlborough’s Account of the Iraq War, March 2003”, in *Naval Historical Review*, September 2003, <https://navyhistory.au/hms-marlboroughs-account-of-the-iraq-war-march-2003/2>.

³ UK Ministry of Defence, *HMS Liverpool Fires on Gaddafi Forces*, 13 May 2011, <https://www.gov.uk/government/news/hms-liverpool-fires-on-gaddafi-forces>.

magazine weight is not as much of a concern on a ship as it is, for instance, on a self-propelled gun on land, naval guns can count on hundreds of ready-to-use rounds.

However, while the strategic and tactical mobility of the naval fire system makes it a very flexible tool, the great proliferation of long-range coastal defence missile systems and drones suitable for anti-ship operations has, however, made littoral warfare operations riskier than in the past, especially from the distances allowed by naval artillery. For example, the Russian K-00P Bastion-P coastal defence missile system has a range of up to 300 km,⁴ while the Vulcano guided ammunition has a maximum range of up to 70 km.⁵

6.1 Naval artillery systems in Europe

European navies, like the majority of the world's navies – equipped with Western weaponry – employ three main naval calibres: 127mm (5-inch), 76mm (3-inch) and 57mm. Smaller calibre, 40mm or less, are of little use in NSFS, because of the limited range and payload.

In addition, the Royal Navy and the French Navy employ two different calibres on their legacy artilleries, which are 114mm (4.5-inch) and 100mm respectively. British gun Mk 8 Mod 1 is a 4.5-inch weapon that can fire a 114mm round (of 20-to-21 kg) at a maximum range of 20 to 27 km.⁶ French Modèle 68 and Modèle 68 TR is a 100mm weapon with a maximum range of 17.5 km and a rate of fire of 78-to-80 round for minute (13.5 kg is the weight of the round).⁷ Both 4.5-inch Mk 8 gun and French Modèle 68 and Modèle 68 TR are near the end of their life-cycle, for that reason new British and French ships are (or will be) equipped with 127mm, 76mm or 57mm guns. These five calibres are not interchangeable/compatible with those employed by land artillery that are standardised on 155mm and on 105mm.

The main calibre used for NSFS tasks is 127mm (5-inch) because of the greater performances in term of range/payload. In this category the most widespread systems, apart from US solutions – Mk 45-gun Mod 0-3 with 54-calibre barrel and Mk 45 Mod 4 with 62-calibre barrel⁸ – are two Italian guns, both produced by Leonardo: the 127/54 Compact and the 127/64 LW (Lightweight).

⁴ Sam Cranny-Evans, "Russia's Coastal Defence Systems: Supporting Limited Naval Capabilities", in *Global Defence Technology*, No. 134 (April 2022), https://defence.nridigital.com/global_defence_technology_apr22/russia-coastal-defence.

⁵ Leonardo Electronics, Vulcano 155, cit.

⁶ NavWeaps website: *4.5"/55 (11.4 cm) QF Mark 8 Mod 0 and Mod 1*, http://www.navweaps.com/Weapons/WNBR_45-55_mk8.php.

⁷ NavWeaps website: *100 mm/55 (3.9") Model 1968, CADAM and Model 1968-II*, http://www.navweaps.com/Weapons/WNFR_39-55_m1968.php.

⁸ BAE Systems, *Mk 45 Mod 4 Naval Gun System Datasheet*, 2020, <https://www.baesystems.com/en-media/uploadFile/20210609205704/1434555552769.pdf>; Eugenio Po, "La torre Mk-45 Mod.4 da 127/62 mm", in *Rivista Italiana Difesa*, No. 3/2005 (March 2005), p. 32-39.

Today, the state-of-the-art weapon in this class is Leonardo's 127/64mm LW, a gun with a rate of fire of 32 rds/min⁹ and a range of 28 to 30 km which is already in service in Italian and German navies, and has been chosen also in the Netherlands, Spain, Algeria Egypt and Canada.¹⁰ Both Italy and Germany employ the gun in combination with the new Vulcano GLR family of ammunitions, though Vulcano is backward compatible with older gun systems. For instance, the Royal Netherlands navy has adopted the Vulcano on the modified 127/54 Compact.

For the land attack role the most advanced artillery system currently in service, is the 127mm Vulcano system that combines the 127/64 LW gun with the Vulcano extended range guided projectile (High Explosives Fin Stabilised Discarding Sabot – HEFSDS), the Automatic Ammunition Handling System (AAHS), and the Naval Fire Control System (NFCS), all by Leonardo.

This system can fire the Vulcano 127mm¹¹ subcalibre ammunition (the projectile has a weight of around 20 kg), both in the guided configuration, the GLR and the unguided configuration, called Ballistic Extended Range (BER).

The GLR Vulcano 127mm ammunition can reach a maximum range of more than 80 km if fired by 127/64mm LW gun – the 127/54 Compact is adaptable to fire this round with a range of over 60 km – a range superior of that of the Vulcano 155mm (around 70 km).¹² Despite the long-range, the accuracy of the Vulcano GLR is very high thanks to its guidance systems.¹³

The 76mm calibre ammunition is fired by Leonardo's "family" of cannons, which includes the Compact, Super Rapid, Strales and Sovraponte versions. All employ the 76/62mm gun, albeit with different rate of fire and different capabilities, and are suitable for firing at targets ashore. The Compact model is the "legacy" gun with a rate of fire of "only" 80 rds/min. Super Rapid, Strales and Sovraponte have a rate of fire of 120 rds/min and Strales and Sovraponte can fire DART guided anti-missile round.¹⁴ In the NSFS role, the 76mm (6-to-6.5 kg round) has a range of 16 km – 20 km with extended range round SAPOMER. However, Leonardo is currently developing a 76mm version of the Vulcano with a predicted maximum range of 40 km.¹⁵

⁹ Leonardo Electronics, *Oto 127/64 LW Vulcano System*, 2022, https://electronics.leonardo.com/documents/16277707/18425031/Cannone+OTO+127_64+LW.pdf.

¹⁰ Eugenio Po, "Il cannone Oto 127/64 LW Vulcano di Leonardo vince in Canada", in *Rivista Italiana Difesa*, No. 6/2021 (June 2021), p. 8.

¹¹ Leonardo Electronics, *Vulcano127*, 2022, <https://electronics.leonardo.com/documents/16277707/0/Vulcano+127.pdf>.

¹² Eugenio Po, "Le artiglierie navali di Leonardo", in *Rivista Italiana Difesa*, No. 1/2019 (January 2019), p. 30-35.

¹³ Eugenio Po, "Il punto sulle artiglierie navali di Oto Melara", in *Rivista Italiana Difesa*, No. 1/2013 (January 2013), p. 43-49.

¹⁴ Ibid.

¹⁵ Leonardo Electronics, *Oto 76/62 SR Super Rapid Gun Mount*, 2022, <https://electronics.leonardo.com>.

The 57mm calibre is employed by the family of 57/70 guns by BAE Systems (Mk 1, Mk 2, Mk 3) and can fire a round of 2.5 kg at a maximum range of 17 km. The 76mm and 57mm guns are less suitable for coastal bombardment due to their small calibre (which means reduced payload and limited range). Like their 76mm counterparts, the 57mm guns are generally unsuited to NSFS missions and, due to limited payload and range, better suited in air- and missile-defence roles.

6.2 The Italian Navy's capabilities

The Italian navy (*Marina Militare* – MM) has great confidence in its naval artilleries, an area in which it has invested heavily and where the national industry has world-leading capabilities. The Navy has a considerable number of 76mm and 127mm guns and is traditionally keen on equipping its ships with a comparatively great number of gun systems.

The new 127/64 LW Vulcano has been fitted on its four General Purpose (GP) FREMM frigates and seven Offshore Patrol Vessels (*Pattugliatore Polivalente d'Altura* – PPA). The Navy is also planning to equip the two upcoming Anti-Submarine Warfare (ASW) FREMM Enhanced frigates and the two Future Destroyer Programme (DDX) destroyers with the 127/64 LW Vulcano.

Today the 127/54 Compact remains in service on a few older units, though the two systems fitted on the De La Penne-class frigates have been modified to fire Vulcano ammunition, as well as the guns of Royal Netherlands Navy.

In addition to the 127/54 guns, the majority of MM units also rely on the 76/62mm gun in its various versions: Compact, Super Rapid, Davide/Strales and Sovraponte for a total of around 30-35 guns across the whole fleet. The main focus of the Super Rapid, Strales and Sovraponte versions are anti-missile and anti-aircraft tasks, whereas the main system dedicated to NSFS the 127/64 LW combined with Vulcano ammunition. Operationally, Navy and Army are working together to achieve full compatibility between the ships' C2 systems and the Italian Army's new artillery C2 system (Joint Digital Indirect Fire Support System – JDIFSS). Thanks to the JDIFSS, which is compliant with the multinational Artillery Systems Cooperation Activities (ASCA), a software tool that links different artillery batteries from partner countries to a centralised C2 centre, Army artillery units will be able to use naval artillery as fire sources, and vice versa.

The Army is also planning to purchase drones to do surveillance and Target Acquisition for Artillery. It is likely that Navy units will also be involved in this type of activity, especially with a view to the Amphibious Joint Land Force, which is made up of elements from the Navy and the Army.

Since the Italian Navy's anti-ship missiles have a secondary land attack capability, artillery capabilities are to be seen as a component of a wider spectrum of land attack/strike tools. However, the current TESEO Mk-2/A missile is limited to coastal targets as it lacks a final guidance system. The future TESEO Mk-2/E EVO¹⁶ is explicitly referred to as "light land attack" missile given the range of over 300 km and its guidance systems also relying on a semi-active laser (SAL) sensor for high accuracy. In addition, the Navy has been studying the possible acquisition of deep strike land attack missiles that can far outrange the current artillery and missile capabilities at its disposal.¹⁷

6.3 Capabilities of other European navies

The Royal Navy has 17 4.5-inch Mk 8 Mod 1 guns in service, while future units will be equipped with US 127/62 Mk 45 Mod 4 and 57mm guns.¹⁸ On the missile side, the Royal Navy is introducing NSM, an anti-ship missile with advanced land attack capability and is upgrading its submarine-launched TOMAHAWK Land Attack Missile.

The French Navy operates a mix of 100mm and 76/62mm Super Rapid guns, while its attack submarines and FREMM ASW frigate (6 ships) are equipped with MdCN (Missile de Croisière Naval), a cruise missile developed by MBDA France with 1,000-to-1,400 km of range with a strong land attack capability.

The German Navy has a mix of 127/64 LW and 76/62mm Compact guns, while more 127/64 LW and new 76/62mm Super Rapid are currently on order.

On the missile side, Germany uses RBS-15 Mk 3 anti-ship missiles (with limited land attack capability) and is introducing in service NSM¹⁹ to replace older HARPOON anti-ship missiles.

The Royal Netherlands navy has 127/54 Compact guns upgraded to fire Vulcano ammunition but plans to replace them with new 127/64 LW gun.²⁰ Other ships have 76/62mm Super Rapid/Strales. Royal Netherlands Navy has decided to acquire the

¹⁶ Eugenio Po, "Il missile TESEO Mk-2/E", in *Rivista Italiana Difesa*, No. 3/2022 (March 2022), p. 20-24.

¹⁷ Eugenio Po, "SEAFUTURE 2023: un salone al di sopra delle aspettative", in *Rivista Italiana Difesa*, No. 8/2023 (August 2023), p. 40-49.

¹⁸ Ezio Bonsignore (ed.), *The World Defence Almanac 2023*; International Institute for Strategic Studies, *The Military Balance 2024*, 2024.

¹⁹ Bundeswehr, *New Submarines and Antishipping Missiles for the Navy*, 9 July 2021, <https://www.bundeswehr.de/en/organization/equipment/news/german-norwegian-submarines-and-antishipping-missiles-5217908>.

²⁰ Eugenio Po "I Paesi Bassi scelgono le torrette LIONFISH TOP di Leonardo", in *Rivista Italiana Difesa*, No. 7/2022 (July 2022), p. 14.

NSM missile²¹ and 76/62mm SOVRAPONTE guns.²²

The Spanish navy has a mix of 127/54 Mk 45 Mod 2 and 76/62mm Super Rapid guns: new frigates will have 127/64 LW by Leonardo²³ and NSM land attack missiles.

6.4 Future prospects for naval artillery

The future of artillery lies in directed energy weapons and electromagnetic cannons, also known as electromagnetic rail guns (EMRG). Among direct energy weapons, which are mainly suitable for anti-air and counter-drone roles, lasers are being installed on US ships and tested in many countries, including Europe, such as the Dragonfire project in the UK, and the Laser Weapon Demonstrator (LWD) in Germany. For naval gunfire, EMRG systems seem the most promising solution for long-range artillery fire, although views differ on this regard. For instance, the US Navy has spent 500 million dollars in the development of an electric-powered railgun before shelving the project in 2021 in favour of increased efforts in developing hypersonic missiles.²⁴ Currently several studies are underway in Turkey, South Korea, Japan, India and China and even in Europe.

At the EU level there have been efforts to study EMRG to complement naval and land-based legacy ordnance and as a hypersonic interceptor. In 2021 EDA launched a consortium, called Projectiles for Increased Long-range effects Using electromagnetic railgun (PILUM),²⁵ in which several industries/universities are involved – ISL, von Karman Institute, Naval Group, Diehl, KNDS France, Explomet, ICAR and Erdyn – to study the feasibility of ERMG – concentrated on the railgun, on the hypersonic projectile and on the energy storage. The aim of this program, funded under PADR (Preparatory Action on Defence Research) and ended in 2023, was to study the feasibility of EMRG to act as future artillery systems capable of delivering projectiles at hypersonic speed over ranges of over 200 km and if they could complement legacy ordnance systems.²⁶

²¹ Xavier Vavasseur, "Royal Netherland Navy Selects NSM – Naval Strike Missile", in *Naval News*, 12 December 2022, <https://www.navalnews.com/?p=40585>.

²² David Foxwell, "New Anti-Submarine Warfare Frigates ordered for Netherlands and Belgium", in *RINA News*, 4 October 2023, <https://rina.org.uk/publications/warship-technology/new-anti-submarine-warfare-frigates-ordered-for-netherlands-and-belgium>.

²³ Eugenio Po "La Spagna ha deciso di acquistare il 127/64 LW Vulcano di Leonardo ", in *Rivista Italiana Difesa*, No. 2 (February 2020), pag. 8.

²⁴ AFP, "US Navy Keeps Electromagnetic Cannon in Its Sights", in *Defense News*, 26 June 2016, <https://www.defensenews.com/naval/2016/06/26/us-navy-keeps-electromagnetic-cannon-in-its-sights>; Udisha Srivastava, "Explained: EM Railgun Technology that the ARDE (DRDO) Has Successfully Developed", in *Indian Times*, 19 October 2022, <https://www.indiatimes.com/explainers/news/-582244.html>; Dorian Archus, "Turkish Indigenous Rail Gun 'Şahi-209' to Be Integrated to Naval Assets", in *NavalToday*, 31 October 2019, <https://www.navaltoday.com/?p=47635>.

²⁵ European Defence Agency, *Ambitious Electromagnetic Railgun Project Surpasses Expectations, Raising Potential of Future Artillery Systems*, 28 September 2023, <https://eda.europa.eu/news-and-events/news/2023/09/28/ambitious-electromagnetic-railgun-project-surpasses-expectations-raising-potential-of-future-artillery-systems>.

²⁶ Ibid.

PILUM was followed by a new European program funded by the European Defence Fund (EDF) – with the same participants plus MBDA Italy and KNDS Italy – called Technology for Electromagnetic Artillery (THEMA). The aim of this new programme is the maturation of the EMRG, preparing for a demonstration test in 2028. Under this effort, a medium calibre EMRG for air defence is expected to enter in service in 2036 while large calibre is estimated to follow in 2040.²⁷

Regarding other countries, China has been carrying out sea trials on EMRG since 2018, while Japan is conducting sea trials since 2023 while India and Turkey have prototypes in development.²⁸

Despite some promising developments, the naval gun is likely to remain the main multirole weapon at least till 2030 if not till 2040.

It is also important to point out that naval guns have been “re-discovered” in their anti-air role (on top of the antimissile self-defence one) to tackle drones used in anti-ship missions. Indeed, the cost-per-kill that a naval gun can achieve against this type of threat is today the best available, to the point that the exchange ratio can even be in the naval gun’s favour if the attacker is using cheap drones. In practice, burst of 76mm gun munitions, even unguided shells, can make the kill at safe distance, as has been demonstrated in the Red Sea by the Italian Navy, German, French and UK navies. In the future, Laser Direct Energy Weapons (LDEW) weapons can further optimise the cost and enhance the capability of dealing with swarming threats. Meanwhile, however, initial LDEW solutions will have limited range and will never offer the same versatility as the current, most advanced naval gun systems and their different types of ammunition.

6.5 Implications for naval artillery

While naval artillery is likely going to retain an important role in anti-air, anti-missile, and counter-drone roles, range, volume of fire and precision remain the main metrics of effectiveness of NSFS activities and surface-to-surface naval warfare. Historically, naval guns possessed sufficient range, overwhelming volume and precision. Yet today, with the proliferation of long-range anti-ship missiles and drones, naval artillery no longer seems to have sufficient range to operate from a safe area and effectively exchange fire with well-armed enemy units.

While guided and extended-range ammunition such as the Vulcano significantly improves the effectiveness of naval artillery, its limited range remains insufficient in the first stages of a peer-to-peer, high-intensity conflict.

²⁷ Shaurav Gairola, “Full Force”, in *Janes Defence Weekly*, No. 17 January 2024, p. 22-27.

²⁸ Kosuke Takahashi, “Japan Performs First Ever Railgun Test from Ship at Sea”, in *Naval News*, 19 October 2023, <https://www.navalnews.com/?p=50546>.

For this type of deployment, the US Navy seems much more oriented towards the employment of guided rockets (HIMARS, MLRS) or even missiles, which allows engaging targets from safe distances. Even so, for any surface-to-surface deployment of naval artillery, accurate targeting solutions remain fundamental, and will depend more and more on the widespread use of UAVs, a capability that needs to be strengthened by many navies, including European ones, both in the area of aircraft operating from warships and in the area of joint operations.

To better integrate naval artillery fire with littoral and land operations, land and naval C2 systems must “talk to each other” more and more deeply. In this regard countries like Italy are on the right track with the C2 onboard ships and the Army Artillery C2s that can handle each other’s guns with the JDFSS. Advanced C2 can reduce sensor-to-shooter timelines, and on a fluid battlefield NSFS can support manoeuvring forces ashore only if it is able to respond at very short notice to calls for fire.

In addition to technical innovations, it is also necessary to rethink and revise existing doctrine in order to account for feedback from the latest operational experiences and threats. Along with doctrine, necessarily, training practices must also be reviewed and updated.

7. Conclusions

by Elio Calcagno and Alessandro Marrone

7.1 The renewed relevance of artillery

Any recommendation regarding the renewed relevance of artillery in warfare must avoid falling into the trap of treating the Ukraine war as a universally-relevant case study that is equally applicable to all armed forces who care to observe and learn relevant lessons.¹ While this conflict offers extremely valuable insights, it is essential that observers also account for its peculiarities. Firstly, although Kyiv benefitted from the supply of many advanced Western weapon systems, these have often been donated in small quantities, much later than originally requested or even in stripped-down versions. Furthermore, the inability of both sides to penetrate the other's air defences with aircraft except with standoff air-launched weapons does not mean true fifth-generation stealth systems like the F-35 would not be able to strike HVTs deep behind enemy lines. Air power, while relatively irrelevant for much of the Russian invasion, will retain a crucial role in NATO doctrine by integrating with artillery and LRF capabilities. In such a context, artillery remains a uniquely flexible and scalable instrument to deliver fires at a distance and concentrate effects from dispersed forces with a persistency that cannot be replicated by crewed aircraft.

In naval warfare artillery is generally outranged by guided missiles (both anti-air and anti-ship), limiting its usefulness in long-range naval engagements with peer-level forces or land-support missions near well defended coasts. At the same time, naval artillery has demonstrated beyond doubt its potential in counter-drone operations, as seen in the Red Sea against Houthi UAVs. These weapons offer excellent value, especially when combined with guided munitions such as the Italian DART/STRALES, which are able to intercept airborne threats at a fraction of the cost of anti-air missiles, making them especially useful when facing swarming threats from the air or the surface. In such contexts, however, these more sophisticated solutions can still be augmented by smaller calibres guns and machine guns, especially for the more rudimentary drones.

7.2 Precision-guided fires

The speed at which a well-drilled and well-equipped force can deliver counter-battery fire on enemy batteries further highlights how important it is for artillery systems to strike their target quickly and precisely in order to move to a new firing position as soon as possible and avoid being hit. Guided rocket and missile systems are of course an ideal solution in many circumstances, but they are expensive and can very easily be spotted from a distance even by the naked eye once they

¹ For more analysis on the Russia-Ukraine war's implications and lessons identified in all domains, see Alessandro Marrone (ed.), *Russia-Ukraine War's Strategic Implications*, cit.

fire. Precision-guided shells such as the Italian Vulcano offer a great alternative from shorter ranges and at a lower cost-per-shell while also being compatible with existing systems. The precision these shells ensure (provided its guidance systems are unhindered) means that a battery should be able to hit its targets with smaller salvos instead of having to saturate the surrounding area with more shots. In the Ukraine conflict the necessity to hit targets with a limited amount of available munitions has highlighted the continued relevance of cluster munitions, which are able to affect larger areas with a single shell. Guided shells may be able to somewhat replicate the effects by hitting targets more accurately rather than striking the general location to achieve the same goal.

At the same time, guided shells rely on guidance systems in order to hit targets and realise their potential. Currently, for instance, Vulcano munitions use a combination of GPS and inertial measurement units (IMU) to reach their objective. As a result, shells of this type are somewhat vulnerable to jamming systems, which could compromise their superior accuracy. This could be overcome by employing a combination of guiding systems with a view to redundancy, including for instance by matching GPS with the Galileo global navigation satellite system (GNSS), and/or using laser terminal guidance capabilities. Vulcano shells can be configured to hit laser designated targets, which however require a forward observer team or an airborne laser designator source to mark the target, adding a layer of complexity to the kill-chain which can be exposed to enemy threats.

In all, the Army's ongoing "vulcanisation" process, by involving as wide an array of artillery systems as possible, could significantly enhance the flexibility of a great number of artillery assets, by increasing range and precision across the board.

For the Navy, guided munitions have opened up plenty of opportunities for the use of artillery as countermeasure to a number of threats at a fraction of the cost required by employing missiles. Guided Vulcano rounds have increased the range at which 127mm guns can engage targets on land as well as at sea over the horizon, while 76mm DART/STRALES guided ammunition have proven to be an ideal counter to UAVs and could be effective also against uncrewed surface vehicles (USV), and against missiles at closer ranges as part of a layered defence system protecting warships.

7.3 A high-low mix

Guided shells are a valuable instrument for close battle manoeuvres given the aforementioned advantages. However, they are also more expensive and can be subjected to jamming countermeasures or expose observer teams behind enemy lines. Military planners will have to decide the right guided-to-unguided ratio as they define the most functional high-low-mix of munitions. Traditional shells are therefore set to continue constituting the bulk of artillery munitions stocks and can still play a central role in land warfare, especially when high volumes of fires are needed in order to saturate a given area over long periods of time. Unguided shells also do not suffer from the payload-vs-guidance system trade-off, meaning

that they can carry more explosive despite being less precise.

Crucially, a truly balanced and effective artillery force cannot hope to achieve the required levels of survivability and effectiveness without being complemented by long-range precision-fires such as missiles, rockets, and short-range ballistic missiles. NATO militaries, including Italy's, still have much to do in order to bring their capabilities up to the required levels across this high-low artillery spectrum and especially in the deep battle manoeuvre space – beyond the deep strike capabilities provided by aircraft.

7.4 Mobility and range equal survivability

When coping with peer-level adversaries in a contested environment, an advanced artillery force faces an arduous challenge as it seeks to deliver fires while avoiding being hit by enemy batteries. In such a context, a battery's combination of mobility and range are directly proportional to survivability. Guided, rocket-propelled, and extended range munitions offer a partial solution to these risks, at least as long as adversary gunners cannot rely on the same range. Self-propelled howitzers such as the PzH 2000 rely not only on excellent range, but also a level of mobility that appears to greatly enhance survivability in the face of fast and precise counter-battery fire. While current towed systems in service in the Italian army and allied forces are still a useful asset – especially when equipped with guided-munitions –, they have become highly vulnerable against a well organised force. The FH-70, with its propulsion unit, offers a less complex, intermediate solution at a lower cost than more advanced self-propelled systems. However, development and subsequent procurement priorities should focus more on the latter, in order to make mobility a more widespread capability within Italian and NATO artillery forces. Furthermore, the ability for future artillery systems to fire while moving is an interesting prospect considering the serious threat caused by loitering munitions, armed UAVs and accurate counter-battery fire in general.

7.5 An integrated fires approach

Artillery in the Ukraine war has largely functioned without the support of combat aircraft. However, NATO allies can count on aerial systems that are much more advanced and capable than Soviet-legacy counterparts and, to a lesser extent, modern Russian ones. With true stealth capabilities ensured by the F-35 and US-operated stealth bombers, NATO forces would likely be able to come close enough to Russian air defences in order to strike HVTs in preparation for/support to ground operations. This does not mean that aircraft can replace artillery strikes as they have done in peculiar scenarios such as Afghanistan, because they will have to face advanced air defences and suffer losses as air supremacy cannot be taken for granted anymore. Against this backdrop, allied capabilities should not only integrate guns and long-range precision-fires, but also air-launched effectors in order to achieve a diverse and flexible strike force that can deliver effects even hundreds of kilometres deep. Tactical drones and loitering munitions should also be considered as an integral part of this force mix as a relatively cheap but

highly mobile and expendable instrument that can augment artillery's effects on the battlefield.² As the Italian Army has noted, this integrated approach requires a new approach to artillery that must encompass doctrine, organisation, training, materiel, leadership and education.

7.6 A fast, resilient kill-chain

Artillery's efficacy depends upon its ability to hit targets reliably while maximising its own survivability. In order to achieve this, a military force must field capable counter-battery systems and ISTAR assets, including drones, satellites, and observer teams. BDA activities are also crucial to ensure tangible and sustainable effects on the field. However, comparatively little can be achieved without trained fire controllers that can prioritise the right targets in the face of conflicting requests and limited assets to fire on them. This requires appropriate training – in terms of both quality and numbers – and an efficient C2 structure, with a degree of decentralisation and increased automation, in order to maximise efficiency. More broadly, in order for an artillery kill-chain to integrate seamlessly into the operational and strategic level, it must be overseen by a C2 structure that is able to exploit the full benefits of such an instrument and coordinate a huge array numerous and diverse assets in real-time.

7.7 Drones: Threat and asset

As in many other fields pertaining to defence, UAVs represent a revolutionary capability: in particular with respect to a military's ability to deliver artillery-based effects when and where they are needed. The war in Ukraine has ushered in a new era of drone operations in that small and relatively-cheap UAVs, including off-the-shelf models, have been used on an unprecedented scale in support of artillery fire by spotting targets, directing fire and assessing damage. However, most NATO armies, including the Italian one, are still struggling to procure these systems in sufficient numbers, let alone integrate them into their units, despite their affordability. Indeed, the supply chain behind this kind of UAVs is largely located in China and other non-Western countries, creating problems of security of supply – and not only – as NATO members do not want to be dependent nor vulnerable to certain third countries. Yet low-end drones continue to be vulnerable to unsophisticated countermeasures and especially EW tools like jamming, which can interrupt the wireless link between the UAV and its operator. Drone operators can also be exposed by the electromagnetic signature linking them to the UAV. Moreover, until drones are capable of more autonomous operation, military units on the ground will have to be followed by a tail of dedicated operators, with possible negative effects on manpower, mobility and logistics. Many lessons on drones' correct use can be drawn from the war in Ukraine, including the fact that – in order to fulfil their potential – these systems must be more autonomous, be acquired in massive numbers, and be integrated into military units at a tactical

² Elio Calcagno and Alessandro Marrone (eds), "Above and Beyond", cit.

level in order to contend with high levels of attrition.

7.8 Counter-battery fire

Counter-battery radars are an essential system in order to carry out counter-battery fire activities. Yet, Italy has invested little in this capability in recent decades due to budget cuts and a defence planning more geared towards peacekeeping, stabilisation, COIN, and counter-terrorism operations. While a much-needed procurement programme is underway to bring the number of counter-battery radars from 4 to 17, no contract has been awarded as of time of writing. Counter-battery radars, however, are as effective as they are vulnerable to detection, meaning that they must be employed in a way that minimises the risk of being hit. Most important of all is a force's ability to achieve fire dominance through reconnaissance superiority and setting an optimal order of target priority.

7.9 More guns, more munitions: The industrial challenge

Similarly to other capabilities, in light of the war in Ukraine and the Russian long-term threat to European security,³ decision-makers and militaries have to re-think their supply and procurement models regarding artillery ammunition. Sporadic and small orders since the early 1990s, typical of the "just-in-time" approach to inventory (where stocks are kept at a minimum until they are needed), have resulted in insufficient stocks throughout NATO (especially in Europe) and limited production capacity. Yet, despite munitions shortage becoming since 2022 one of the key talking points in the policy debate, serious difficulties persist. While there has been a general increase in defence budgets in Europe over the last two years, shell stocks replenishment currently competes with other urgent procurement priorities for limited resources. Yet, the credibility of NATO's conventional deterrent depends firmly on the ability to withstand a high-intensity conflict for more than just a few weeks and, therefore, on adequate munition stocks – including rockets and missiles. Restocking artillery forces nevertheless would require years, not months, of growing investments.

Gun barrel manufacturing has also been maintained at the bare minimum, meaning that industries – drawing from lessons highlighted by the conflict in Ukraine – are having to invest in revitalising their manufacturing capacity. While a "just-in-case" approach to supply chains – where stocks are kept at high levels by default in case a conflict erupts – is not realistic across the entire spectrum of defence procurement, it appears to be necessary when it comes to artillery ammunition.

With regard to ammunition, the European Defence Industry Reinforcement through common Procurement Act (EDIRPA) is a welcome initiative that Italy should exploit, yet it focuses on the finished product and not on the raw and processed materials that make up munitions. Here the European Defence Technological and

³ Alessandro Marrone (ed.), *Russia-Ukraine War's Strategic Implications*, cit.

Industrial Base (EDTIB) faces a stiff challenge given its dependency on foreign suppliers for steel and explosive materials. This is already creating delays in supply and raises in overall cost, especially at a time when many militaries are looking to replenish and build up stocks. Single countries and the EU must support the industry with adequate policies in order to alleviate this dependency and avoid fragmented and competitive demand. This issue extends to all defence-related fields and should not be left to languish as a secondary priority given the obvious implications on Europe's "defence readiness" – a key goal of the 2024 European Defence Industrial Strategy.⁴ In practice, the EU could increase the share of its annual budget dedicated to co-financing defence-related initiatives, incentivise EU cooperation through fiscal exemption of defence expenditure and reimbursing EU member states donating weaponry to Ukraine.⁵ The latter point is particularly relevant in the field of artillery systems and munitions, seeing as so much of the donations belong to these categories. Given that there are only a few munitions producers in Europe, the EU must also contribute to strengthening the security of supply of its member states by eliminating any obstacle to the intra-community transfer of ammunition and by encouraging a "European" logic in the prioritisation of supplies. Such approach will be crucial in order to avoid that smaller member states who depend on other EU member states' industries are ensured the required supplies without risking being supplanted by orders from those same member states' armed forces or other preferred countries.

Finally, Italy and NATO allies ideally need to significantly increase the number of available artillery systems. The war in Ukraine is a clear reminder of the importance of fielding enough effectors so that some can carry out offensive fire operations while others focus mostly on counter-battery fire.

In the Red Sea, artillery has proven to be an ideal and cost-effective counter to unsophisticated Houthi drones. Italian warships are notoriously well-armed with 76mm guns, which are also effective against anti-ship missiles, compared to many allied counterparts, putting them in a better position than most. Yet here too the issue of munitions stocks (in port and onboard) must be tackled urgently in order for warships to be able to fend off sustained swarm attacks and maximise staying power in the area of operations.

As for the Italian industry, the early efforts made into guided munitions will require continued investment in order to maintain its important role and adapt the technology to ever-evolving challenges and requirements, also in light of lessons observed in the Ukraine war.

⁴ European Commission DG Defence Industry and Space website: *EDIS | Our Common Defence Industrial Strategy*, https://defence-industry-space.ec.europa.eu/node/557_en.

⁵ Alessandro Marrone and Michele Nones, "Come e perché sostenere la difesa dell'Ucraina", in *AffarInternazionali*, 22 Aprile 2024, <https://www.affarinternazionali.it/?p=107904>.

7.10 Focus on training

Italian artillery forces have for too long suffered from the inability to properly train at national firing ranges, forcing the Army to significantly cut down on training and eventually seek alternative opportunities abroad. The Navy too has encountered difficulties due to outside pressure, raising costs and limiting the amount of live fire training that can be carried out. This points to the importance for the armed forces to be able to have access to large and continuously usable areas on Italian territory. Decision-makers should support the MoD in finding solutions that are cost-effective and sustainable in the long term, allowing gun crews to train to an adequate level of proficiency. Training should also focus more on dispersed operations and account for a greater threat to survivability than the Army's artillery component has prepared for since the end of the Cold War.

In conclusion, as technology and warfare continue to advance and influence one another, artillery remains a fundamental tool across different domains. It is essential then that militaries are not only well-equipped with capable artillery systems in sufficient numbers, but also able to use them proficiently in the face of evolving threats on the battlefield.

Updated 10 July 2024

Acronyms

A2/AD	Anti-Access/Area Denial
AAHS	Automatic Ammunition Handling System
APS	Active Protection System
ALaMO	Advanced Low-Cost Munitions Ordinance
APU	Auxiliary Power Unit
ARTHUR	Artillery Hunting Radar
ASCA	Artillery System Cooperation Activities
ASW	Anti-Submarine Warfare
ATACMS	Army Tactical Missile System
BCT	Brigade Combat Teams
BDA	Battle Damage Assessment
BER	Ballistic Extended Range
C2	Command and Control
CEP	Circular Error Probable
CG	Guided Missile Cruiser
COIN	Counterinsurgency
DDG	Guided Missile Destroyer
DDX	Future Destroyer Programme
DoD	Department of Defence
DPICM	Dual Purpose Improved Conventional Ammunition
DRS BCT	Deep Reconnaissance Strike Brigade Combat Team
EABO	Expeditionary Advance Base Operations
EDF	European Defence Fund
EDIRPA	European Defence Industry Reinforcement through common Procurement Act
EDTIB	EU Defence Technological and Industrial Base
EI	Esercito Italiano
EMRG	Electromagnetic Rail Guns
ERCA	Extended-Range Cannon Artillery
EW	Electronic Warfare
FOB	Forward Operating Base
FPV	First Person View
FY	Fiscal Year
GLR	Guided Long Range
GMLRS	Guided Multiple Launch Rocket System
GNSS	Global Satellite System
GP	General Purpose

GPS	Global Positioning System
HE	High Explosives
HEFSDS	High Explosive Fin Stabilised Discarding Sabot
HIMARS	High Mobility Artillery Rocket System
HVP	Hypervelocity Projectiles
HVT	High-Value Target
IFV	Infantry Fighting Vehicle
IMU	Inertial Measurements Units
INF	Intermediate Nuclear Forces
INS	Inertial Navigation System
ISTAR	Intelligence Surveillance Target Acquisition and Recognisance
JDIFSS	Joint Digital Indirect Fire Support System
JLTV	Joint Light Tactical Vehicle
LCS	Littoral Combat Ship
LDEW	Laser Direct Energy Weapons
LINAPS	Laser Inertial Navigation Artillery Pointing System
LRF	Long-Range Fires
LWD	Laser Weapon Demonstrator
LRHW	Long-Range Hypersonic Weapons
MBT	Main Battle Tank
MdCN	Missile de Croisière Naval
MDTF	Multy-Domain Task Force
MDO	Multy-Domain Operations
MLRS	Multiple Launch Rocket System
MM	Marina Militare
MPF	Mobile Protected Firepower
MVR	Muzzle Velocity Radar
NEMSIS	Navy/Marines Expeditionary Ship Interdiction System
NFCS	Naval Fire Control System
NSFS	Naval Surface Fire Support
NSM	Naval Strike Missiles
PADR	Preparatory Action on Defence Research
PGK	Precision Guidance Kit
PILUM	Projectiles for Increased Long-range effects Using electromagnetic railgun
PPA	Pattugliatore Polivalente d'Altura
PrSM	Precision Strike Missile
ROGUE	Remotely Operated Ground Unit for Expeditionary
SAL	Semi-Active Laser
SIMRF	Strategic Mid-Range Fires

SINGINT	Signal Intelligence
SPH	Self-Propelled Howitzer
THEMA	Technology for Electromagnetic Artillery
UAS	Uncrewed Aerial System
UAV	Uncrewed Aerial Vehicle
USV	Uncrewed Surface Vehicles (USV)
VSHORAD	Very Short-Range Air Defence

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