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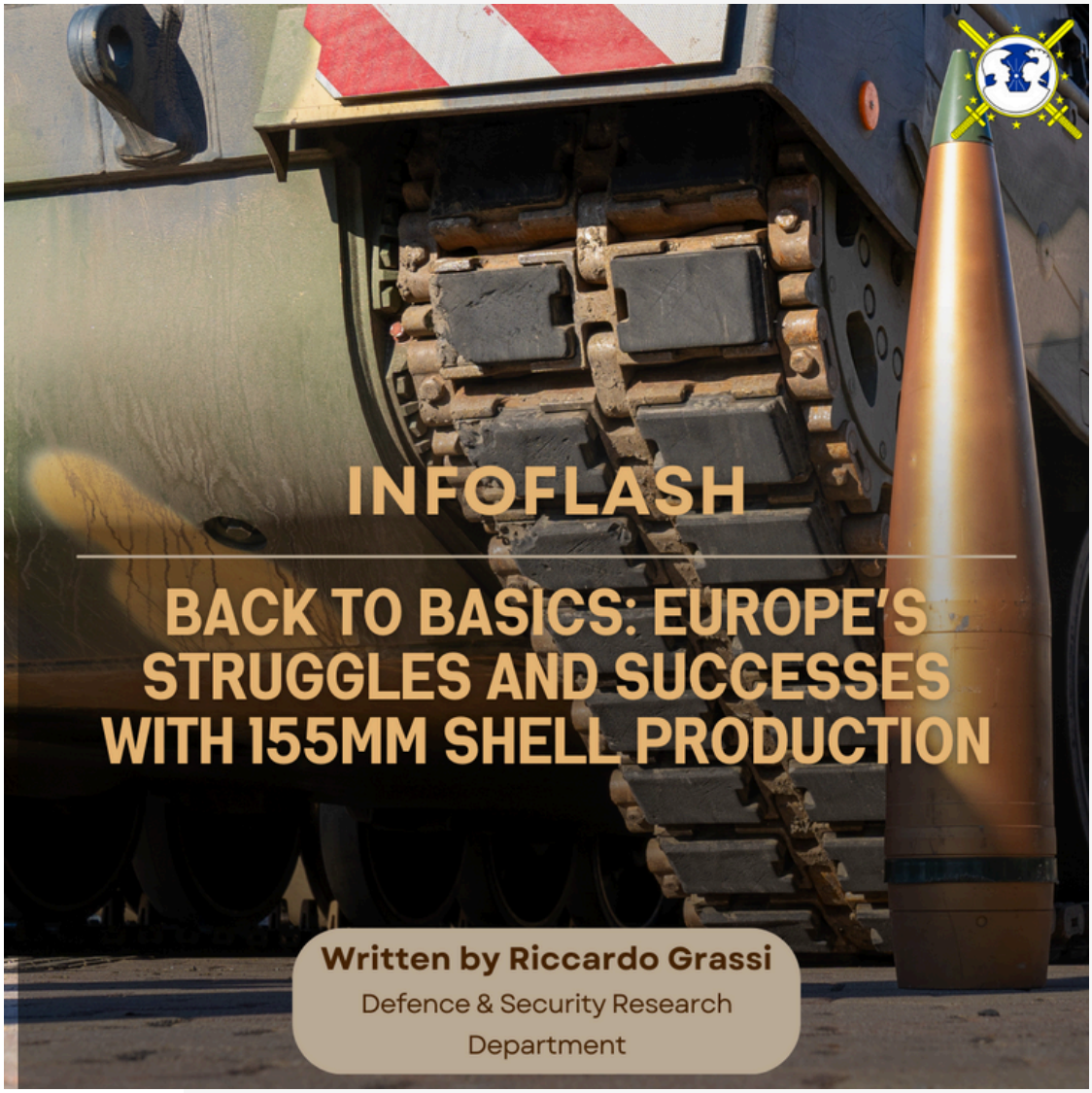

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Introduction

The early days of the war in Ukraine seemed to favour agile and relatively innovative capabilities which appeared to be the new protagonists of future battlefields. In fact, the fate of the war appeared to rest on Stingers and Starstreaks, Javelins and NLAWs, FPV commercial drones and on the Bayraktar TB2. However, as the chaotic first phase of the conflict ended, the focus shifted to the centuries-old king of battle: artillery. Much has been written on the rediscovered importance of artillery at the tactical and operational levels (Oltei, Potin, & Clarke, 2024). In contrast with the precision-oriented doctrine prevalent in the West, the war in Ukraine is revealing how precision-guided munitions can only complement and not substitute conventional indirect fire. The industrial capacity to produce this military ordinance en masse can indeed still determine victory on the battlefield. This analysis will thus focus on the 155mm NATO-standard artillery shell, the European states' ability to produce it, and their significant shortcomings and progress.

The NATO-standard 155mm Shell

While the 155mm artillery shell is not a single piece of equipment, all the different types and models of 155mm shells are standardized under the 2009 Joint Ballistic Memorandum Of Understanding (JBMoU) between France, Germany, Italy, the UK, and the US (Department of State, 2009). The governments of these states, "recognizing the benefits to be obtained from standardization, rationalization, interchangeability, and interoperability of military equipment" (Department of State, 2009, p. 4), adopted the JBMoU so that the 155mm ammunition produced in one country could be fired by the artillery weapons systems of another country.

The most commonly used type of artillery shell is the High Explosive (HE) one. The basic composition of a HE shell is simple: a hollow steel casing, filled with explosive material – usually TNT, RDX (exogen), composition b, PBX (Polymer-bonded explosives), or other Inert Materials – and a fuze screwed on top which ignites the explosive on impact or in proximity to the target. 155mm shells can be fired from either l52-calibres or l39-calibres, according to the length of the barrel (GlobalSecurity.org, 2019): the longer the barrel, the greater the range. The most basic model of shells is the old American M107 HE with its European counterparts (General Dynamics, 2017), Nexter's LU 107 (Nexter, 2022) and BAE Systems' L21 HE (BAE Systems, 2023). It weighs 43.2 kg, of which 6.6 kg are explosive filling, fired from a l39 barrel (like the M777 howitzer) and with a maximum range of 18.7 km. Newer shell models boast better characteristics. For example, the M795 HE (General Dynamics, 2020), the M107 HE replacement, has an increased range of 22.5 km while carrying an additional 4 kg of explosives. These improved capabilities are possible thanks to technological improvements such as the base bleed system, a metal ring attached to the bottom of the shell that propels gas. The propelled gas increases the pressure behind the shell in flight, thus greatly reducing drag (Nammo, 2020). European conventional shells can be fired from greater calibers, since European armies are equipped with l52-caliber barrels (the German Panzerhaubitze 2000, the French CAESAR, the British Archer, and the Spanish Santa Bárbara) and, therefore, have a longer range— up to 40 km.

This is the case with Nexter's *LU211* (Nexter, 2022), BAE Systems' *XL12E1* (BAE Systems, 2023), Rheinmetall's *M2000* (Rheinmetall, 2021), and Nammo's *High Explosive Extended Range* (Nammo, 2023).

Finally, 155mm shells can reach further levels of sophistication, like Extended Range-Velocity Enhanced Artillery Projectiles and GPS-guided munitions. This is the case for Raytheon and BAE Systems' Excalibur (Raytheon & BAE Systems, 2007) and Leonardo and DIEHL's Vulcano (Leonardo & DIEHL, 2021) shells. Nevertheless, the cost of sophistication makes their mass production prohibitive: while a conventional shell costs between $3,000 and $5,000 (Svoke, 2024), one Excalibur round is worth around $100,000 (Peck, 2024).

European Industrial Production

The European and American ways of producing 155mm shells are substantially different (Svoke, 2023). In the US, production is concentrated at the Scranton Army Ammunition Plant, which is operated by General Dynamics but owned by the Army (General Dynamics, 2021). In Europe, production is a private enterprise, with nine companies – plus their subsidiaries – that commercially manufacture the ammunition: Rheinmetall, Nexter, BAE Systems, Nammo, MSM Group, STV Group, Dezamet, CSG Defence and Hellenic Defence Systems (Aries, Giegerich, & Lawrenson, 2023). The difference in the production structures means that European states cannot influence the surge in the amount of munitions manufactured as directly as the US. The current European insufficient production capability is aggravated by a long period of under-investment in military affairs. After the end of the Cold War, Western Europe was eager to collect its peace dividend and "the emphasis changed from readiness to efficiency – to doing more with less" (Aries, Giegerich, & Lawrenson, 2023, p. 8). While this is certainly true, the problem of insufficient ammunition stocks is not just a product of post-Cold War complacency. According to a memorandum to the UK Minister of State for Defence, in case of intensive fight breaking up in Europe, the British Army of the Rhine, part of the Northern Army Group tasked with stopping a Soviet invasion, would have depleted its stock of 155mm shells in two and a half days in 1980 (White, 2017).

Aggregate estimates of Ukrainian consumption of artillery shells are not easy to calculate. The rate of fire is not uniform throughout the year but varies according to operational needs and material supply. according to Ukrainian MP Oleksandra Ustinova (Ataman & Sebastian, 2023). More recently, Ukrainian Defense Minister Rustem Umerov (Nardell, 2024) wrote to European ministers that artillery fire rates had drastically dropped to 2,000 shells per day (60,000 a month). Both numbers are well below what the former Ukrainian Minister of Defence, Reznikov, considered the minimum mission requirements (356,400 a month) and what is required for full firing capacity (594,000 a month) (Bounds, 2023). At the beginning of Russia's invasion of Ukraine, Europe was able to produce 230,000 shells a year (Svoke, 2023). In other words, European annual shell production in 2021 would have been enough for the Ukrainian artillery to fire at capacity for about 11 days.

The Reasons for European Shortcomings

European shortfalls in procuring a satisfactory amount of 155mm have four main causes:

1.The need for long-term contracts: companies need reassurance that the demand for this kind of goods will be sustained over medium to long term periods. For them, it does not make sense economically to have a short spike in production for a couple of years only to go back to the usual lower levels after the crisis has passed. The investment the company made in infrastructure, personnel, and securing raw materials would then go to waste and companies are not willing to take such a financial risk (Jones, 2023, p. 12).

2. Industrial capacity: the particular nature of manufacturing military hardware makes it a relatively rigid supply that cannot easily meet a surge in demand. Difficulties in plant expansion, factory conversions, and skilled labour shortages make it difficult for military ordinances to meet a surge in demand. An EU official revealed to Politico, "we came to the limit of what can be done with existing industrial capacity" (Posaner, 2024).

3. The political nature of the market and raw material scarcities: the limit of European industrial capacity cannot be easily compensated through trade. First, because geopolitical tensions restrict the freedom of trade between competitors. The Chinese People's Liberation Army employs 155mm shells, but it is unlikely that Bejing would be willing to sell ammunition to Europe. Second, for mercantilistic and security purposes, European countries prefer to rely on domestic production (Svoke, 2024). Preferences for domestic manufacturing are not limited to the final product. Europe aims to secure the supply of all products necessary for shell production. In particular, the supply of explosives has been strained by the increased demand for ammunition (Aries, Giegerich, & Lawrenson, 2023, p. 9). Nevertheless, relying on countries such as China to import these goods is no longer seen as prudent. The Financial Times reported on the growing discomfort of European arms producers about the market dominance of Chinese cotton lint, a byproduct of cotton which is used to produce nitrocellulose, an essential ingredient for gunpowder (Alim, Nilsson, & Pfeifer, 2024).

4. Long lead times: even without the impediments so far discussed, ramping up production would still require time. Jones from the Center for Strategic and International Studies (2023) underlined how the production time for certain types of missiles is two years. Even for less sophisticated weapons such as 155mm unguided shells, it takes between 10 to 20 months from order to delivery, according to a French parliamentary report (Assemblée Nationale de France, 2023, p. 57).

Progress

Despite the challenges, Europe has been ramping up production. From an initial rate of 230,000 a year, the European Commission (2024) states that, as of January 2024, Europe has the industrial capacity to produce 1 million 155mm shells per year. This impressive increase in production was possible thanks to European initiatives such as the March 2023 *Collaborative Procurement of Ammunition* (CPA) set up by the European Defence Agency (2023), the Commission's *European Defence Industry Reinforcement through common Procurement Act* (EDIRPA) (2024a), and especially the *Act in Support of Ammunition Production* (ASAP) (2024b). The first two initiatives aim to alleviate the need for long-term contracts: "Aggregating EU demand on a wider scale will provide the EU defence industry with stronger and more long-term signals to ramp up its manufacturing capacities and make the defence market ready to face a changed security environment" (European Commission, 2024a). ASAP's purpose, instead, is to answer to the industrial capacity, raw material scarcities and political concerns. ASAP consists of €500 million in lump sum grants for up to 45% of the cost of capacity and supply-chain resilience-enhancing projects. Out of the total, €124 million went to increase explosive production, €248 million to powder production, and €90 million to shell production. As a result, companies such as Rheinmetall (Hoffmann, 2024), Nexter (Domingo, Nexter's Ammo Output to Increase Eightfold Following EU Grant, 2024), and Nammo (Domingo, 2024) took advantage of the Commission's grants to expand their manufacturing capacity.

Conclusion: The Complacency Trap and the Way Forward

According to an EU official speaking to Politico's journalist Posner under the condition of anonymity, EU manufacturing capacity should reach between 1.4 and 1.7 million shell units per year in 2024 and 2 million by the beginning of 2026, including also 152mm Soviet-era shells produced in Eastern Europe (Posaner, 2024). This is surely good news for European defence. What the EU official said next is more controversial: "We consider that having an industrial base of ammunition 2 million to 2.5 million is what is needed" (Posaner, 2024). On paper, 2.5 million seems like a significant figure, enough to guarantee Europe's security. However, if one has a closer look at the numbers, the picture that emerges is not as encouraging. According to the International Institute for Strategic Studies' Military Balance (2024, p. 72-156), EU states can count on 1,885 units of 155mm barrels, between self-propelled and towed artillery. Even if one assumes that only one-quarter of those barrels would be used in a large-scale conflict involving EU states, a yearly production of 2.5 million units would correspond to a fire rate of about 15 shells per day for each weapon system. Modern weapon systems such as the Archer Mobile Howitzer can fire eight rounds in one minute, making this production volume clearly inadequate (BAE Systems, 2023, p. 2).

Naturally, Europe should be able to draw from stocks and not rely on active production only. However, aid to Ukraine has dried up European reserves and will continue to slow their replenishment (Lopatka, 2022).

Although one could argue that European states would rely more heavily on air power for Close Air Support and indirect fires, the war in Ukraine has demonstrated that air dominance cannot be taken for granted. Moreover, decision-makers might be reluctant to risk sophisticated aircraft when artillery could achieve the same results. Therefore, Europe should see a yearly production of 2.5 million shells as a progressive improvement and not the end goal.

Lastly, Aries et al. (2023), see industrial consolidation as a necessity to further increase industrial capacity and achieve large economies of scale. Conversely, Andersson (2023) of the EU Institute for Security Studies warns that consolidation might stymie competition and deter innovation. Therefore, it is arguably wiser to encourage competition among firms by enforcing competition rules more strictly and avoiding protectionist tendencies among EU states. Europe must find a way to increase its industrial capacity and at the same avoid making an already oligopolistic market even less competitive. A monopoly in this sector could have negative political and economic repercussions. Rather than consolidating the supply, it would be wiser to unify the demand side by enhancing initiatives like the CPA and the EDIRPA. On the one hand, bigger communitarian contracts would lower the price of the individual ammunition procured, thus increasing single countries' bang for the buck. On the other hand, a greater freer market would push companies towards innovation and efficiency through competition. The companies that can survive market competition are the best suited to answer Europe’s growing security needs.

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