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High Energy Lasers
Tactical Tool or Star Wars?

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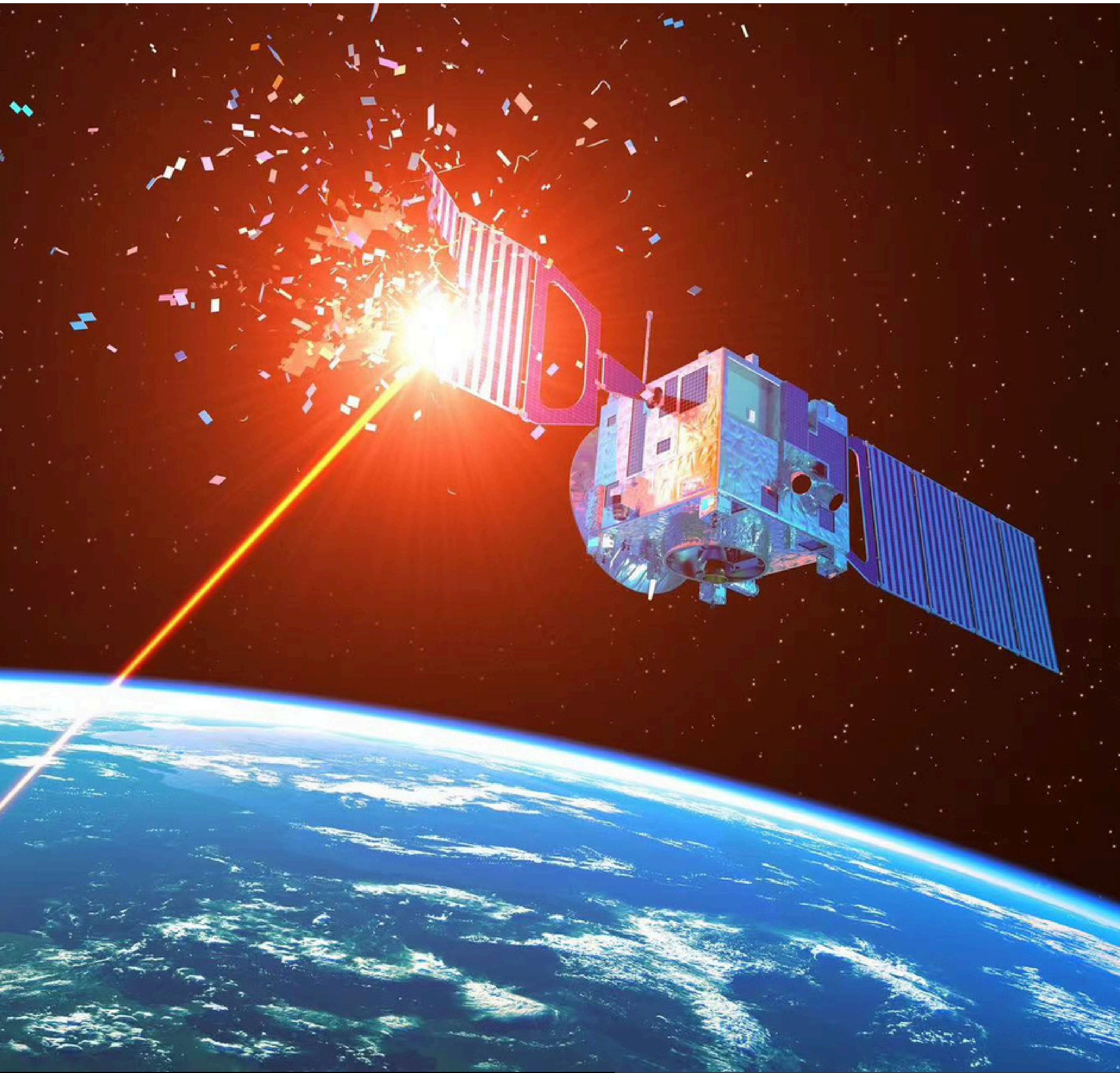

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FINABEL's Research Reports are concise, research-driven publications designed to keep Europe's defence community informed about the latest strategic, military, and geopolitical developments. Released three times per week, these short-form papers offer timely analysis on emerging trends affecting European land forces. Each Research Report is produced by the researchers of FINABEL's Permanent Secretariat, in the goal of supporting decision-making across the European defence landscape.

RESEARCH REPORT

Introduction

In 2024, the United Kingdom's Ministry of Defence announced that the DragonFire High-Energy Laser (HEL) would be deployed on its Navy's ships by 2027 (Shapps, 2024). The first deployment of its kind in Europe, DragonFire provides counter-Unmanned Aerial Systems (c-UAS) and counter-rocket, artillery, and missile (c-RAM) capabilities (Shapps, 2024). HELs can also upset Mutually Assured Destruction (MAD) calculations because it outpaces hypersonic missiles (Snow, 1980, p. 289), frustrate Intelligence, Surveillance, and Reconnaissance (ISR) efforts (DiMascio et al., 2024) and provide easy and efficient drone "hard kill" capabilities.

Europe requires these abilities against a dire threat picture: Russia has allegedly equipped its Strategic Missile Forces with the Perveset HEL and deployed its purportedly more advanced "Zadira" HEL in Ukraine (Falconbridge, 2022). While the former can only blind satellites at a height of 1,500km, the latter can allegedly destroy the targets by "burning them up" (Falconbridge, 2022). September 2025 also saw a troubling pattern of Russian aerial incursions into European airspace (Edwards, 2025), many of which were by UAS. Further, non-state actors have also started to use more drones (Clausen, 2024), with groups such as Daesh and the Houthis using commercial off-the-shelf drones equipped with explosives in aerial bombing operations (Archambault and Veilleux-Lepage, 2024). Europe will be worse off if it does not quickly develop and deploy HELs, as its adversaries would hold a strategic edge against it, and because Europe would have one less means of defence against attacks on military and civilian infrastructure. HELs are also worth paying attention to because of their low operation costs; while innovating and developing them may be cost-intensive, their logistical and operational costs are extremely low. This should be attractive to a budget-constrained Europe that is seeing less financial support from traditional security guarantors like the United States.

However, despite the increasingly dire threat picture and HELs' advantages, Europe has somewhat lagged in HEL development. While the UK is ready to deploy its HEL, mainland European nations are still in the demonstration phase. Hence, it is worth asking if, and how, Europe should be more aggressive in its HEL strategy. This paper argues that despite technical challenges of line-of-sight, thermal blooming, toxic byproducts, and power source dependencies, HELs alter MAD calculations and offer cheap battlefield and city-based aerial defence as well as the disruption of adversary intelligence collection efforts. These benefits justify a more coherent approach towards HEL development, which may hasten the resolution of technical challenges. Hence, Europe should centralise its HEL research and development by: (i) creating channels for different working groups to share ideas and lessons learned; (ii) changing procurement rules to allow the deployment of a minimum viable product and take feedback from combat personnel; and (iii) crowding-in the sector with industry players to allow for better solution generation.

2. What is a HEL, and how does it work?

The HEL belongs to the Directed Energy Weapons (DEW) family, which more broadly covers "weapons that [use] a directed beam of electromagnetic radiation, supplied by particle beams, high-power microwaves, or a high-energy laser" (Borja, 2023, p.1). There is no widely accepted definition of what constitutes a High Energy Laser; however, it is useful to order lasers by tactical effects. For context, a 1-watt laser pointer can permanently blind an individual (Angell, 2012, p. 116). HELs, in comparison, operate in the range of 10 kilowatts (kW) to hundreds of kWs. Weaponised HELs of less than 100kW are strong enough to temporarily blind satellites or even destroy drones with as little as two seconds of exposure (Angell, 2012). Weapons above 100kW can be used for base and aerial defence, while weapons above 300kW can be used for missile defence and other strategic purposes (DiMascio et al., 2024).

Most HELs comprise three parts: (i) a gain medium, which contains an element that can attain an "excited" state and produce photons when they descend back to a normal state (Ditmire, 2017); (ii) a pump source, which is responsible for "exciting" the medium; and (iii) an optical resonator (usually mirrors), which reflects and multiplies photons produced by the excited material. A laser is produced when the photons are released through an opening or a semi-transparent optical resonator. (Moran, 2012, p. 54)

While there are several types of HELs, contemporary HELs are commonly Chemical-Oxygen Iodine Lasers (COIL) or solid-state lasers. They have different types of gain media, pump sources, and optical resonators. In a COIL, the pump sources are hydrogen peroxide and chlorine, which react to produce oxygen. The oxygen is pumped into the gain medium, which contains iodine. The oxygen excites the iodine, which produces photons when it returns to its normal state. The photons are reflected across mirrors before exiting as a laser. While a COIL has reliably produced HELs in the past, it is difficult logistically as it requires toxic materials as its input, produces hazardous materials as by-products, and risks corrosion from repeated exposure to these chemicals. In solid-state lasers, the process starts by electrifying diodes that excite a solid material (such as crystal) which has been mixed with rare-earth materials like ytterbium or neodymium. The photons produced are then reflected across mirrors before exiting as a laser. (Moran, 2012). These technical details are important to understand: (i) how much energy is required to neutralise a given threat; and (ii) technical challenges with HEL deployment.

3. What are the strategic and tactical benefits of HELs?

3.1 *Strategic*

Strategically, HELs can upset Mutually Assured Destruction (MAD) calculations. MAD dictates that a nuclear escalation assures the destruction of all parties involved (Britannica, 2025). Should one country fire nuclear weapons onto another nuclear-protected country, the failure to eliminate second-strike capabilities assures a reciprocal attack, resulting in the destruction of both countries. Thus far, modern anti-missile capabilities have not been able to quickly sense and deploy countermeasures to neutralise nuclear threats during its travel (Zimet, 2002), because of the time taken to detect a launch, diagnose it as legitimate, and decide on a response. Hence, kinetic countermeasures travel too slowly to neutralise an airborne hypersonic missile with a nuclear warhead.

HELs, which are speed-of-light weapons, travel faster than hypersonic missiles and can neutralise them in time. Further, should countries be able to sense a nuclear launch, HELs may allow countries to neutralise nuclear threats during the "boost" phase, a vulnerable phase for the missile given its full fuel tanks and weakened external structure (Zimet, 2002). While such strategic lasers require high power and range, the U.S. is already developing a satellite-based megawatt HEL that can neutralise such threats (Obering, 2019). HELs thus equip countries with the ability to neutralise nuclear threats once the decision is made to do so, which allow for a reliable and accurate defence against a nuclear first-strike and alter MAD considerations. Indeed, an efficient and reliable nuclear missile defence system may cause several changes to national nuclear doctrines and deployment strategies.

3.2 Tactical

Tactically, HELs provide small units with easy and cheap drone countermeasures and armies with the ability to frustrate ISR efforts.

HELs allow small units to destroy drones. Extensive battlefield drone usage has prompted a change in land doctrine. Russian tanks are heavily camouflaged to avoid drone sensors (Hernandez and Gibbons-Neff, 2025). Both Russia and Ukraine use motorcycles and All-Terrain Vehicles on the battlefield, using speed, stealth, and agility to evade drones (McGovern, 2025). At worst, countries have used Patriot missiles, at 3 million euros a round, to destroy 1000-euro drones, which financially exhausts those without cost-efficient c-UAS capabilities (Kremidas-Courtney, 2025). However, belligerents resort to such means because there are few ways to easily, cheaply and efficiently "hard kill", or destroy, a drone (Chaari and Al-Maadeed, 2020). Such methods, such as GPS jamming or spoofing, require technical expertise (Sharma, 2022, p. 232). However, these methods are circumventable with autonomous capabilities (Khawaja et al., 2022). In contrast, HELs above 10kW afford small units the ability to burn through a drone's airframe, ensuring its cheap and complete destruction (Khawaja et al., 2022, p. 5 and Angell, 2012).

HELs can also temporarily or permanently blind optical sensors. In doing so, HELs can disorientate adversary forces as they lose their ISR capabilities intelligence. High-energy lasers have been found to introduce saturation into pictures generated by infrared cameras, rendering the final images as a splotch of white without useful information (Schleijpen, 2008). Lasers can also cause irreversible damage to optical sensors on both aerial and orbital platforms (SPARTA, 2025 and Zheng et al., 2024). Such capabilities significantly affect an adversary's anticipation, intelligence, and planning. Military planners may not have the intelligence required to draw up well-informed plans, nor might battlefield units have forward warning on imminent threats. Not only does this deny mission success to adversaries; it also decommissions entire ISR platforms, impacting an adversary's long-term intelligence collection capabilities.

Finally, the HEL is logistically easy to deploy. Firstly, the cost-per-shot for HELs are low; each DragonFire shot cost only 10 pounds (Faulkner, 2024). The magazine itself is "deep": the number of shots is dependent on the power source's ability to continue the pumping process (Borja, 2023; Zimet, 2002). Solid-state lasers are powered by electricity, relieving logistics units from bringing specific ammunition to frontline units in resupply missions. Training is cheaper, as the cost-per-shot for HELs is far lesser than that of its kinetic equivalent (Black, 2024). The combination of cheap shots, limited space required for ammunition, logistical ease, and cheaper training make HELs an efficient and cost-effective solution in budget constrained environments.

3.3 *Challenges of HELs*

HELs currently face many technical challenges. Firstly, HELs require line-of-sight (Black, 2024 and Borja, 2023); if operators cannot see the target, it will be difficult for them to fire the laser accurately. Second, weak lasers are still subject to "thermal blooming", where light is absorbed by the atmosphere (Borja, 2023, p. 5 and Zimet, 2002). This reduces their destructive capacity. Thirdly, HELs require a power source that may be difficult to transport. In the case of a COIL weapon, the chemicals involved are not only corrosive but also toxic (LaFortune et al., 2007), endangering operators who may have to transport such chemicals over large distances without protective equipment. Fourthly, reloads may take time as the weapon's extensive use increases the temperature of the gain medium, causing the inner housing of the laser to melt if not cooled properly (LaFortune et al., 2007). Advanced cooling requirements and pumping ingredients, if heavy, will hamper the speed and agility of infantry units, reserving HEL use only for vehicles and aircraft. However, these challenges can be overcome through more intensive R&D.

4. What has Europe done so far?

Europe's development of HELs has been haphazard. While the UK is ready to deploy its DragonFire HEL on its ships in 2027, European companies are still in the demonstration stage. In 2024, Leonardo and MBDA signed an MOU to develop a HEL counter-drone system for the Italian Navy (MBDA, 2024). Italy and Spain partnered under the PESCO platform to create a 10kW to 100kW laser which can "hard kill" small and fast UAS (PESCO, 2025). The French Navy has also successfully tested the 2kW HELMA-P, which is efficient against small drones (Army Technology, 2024) and was deployed during the 2024 Paris Olympic Games (CALIS, 2024). Germany has similarly deployed a HEL demonstrator on the Sachsen, a frigate (Kremidas-Courtney, 2025).

The TALOS-TWO project is a significant effort at harmonisation. Led by CALIS, a French defence company, the project brings together a consortium of 21 companies, including France's Ariane Group, Germany's Rheinmetall and Airbus Defence and Space Group, and Italy's Leonardo. The project is funded by the European Defence Fund (EDF) and aims to create a 100kW HEL that can destroy armoured targets and larger missiles at long distances. (European Defence Fund, 2024) The project is a step in the right direction: the consortium integrates the European HEL supply chain, allowing them to share knowledge and findings, reduce redundancies, and improve interoperability.

However, the environment remains fragmented. While it may be economically efficient for different parties to diversify their efforts across the HEL spectrum, it is unclear if the various developing agencies – especially companies like Leonardo that are involved in HEL projects across power variants and countries – are communicating with one another or internally. Second, it is unclear if lessons learned from developing 10kW HEL are being shared with teams developing a 100kW HEL, and vice versa. Finally, it is unclear if practitioners are contributing to the development of TALOS-TWO, or whether it is being trialled by national or NATO militaries. All in all, these shortcomings may hamstring the rapid development and deployment of lasers against a dire threat picture of a drone-biased environment with emerging laser-based missile defence capabilities. Hence, if budget-constrained, Europe should consider reorganising its HEL R&D efforts to eliminate redundancies, involve more practitioners, and crowd-in the sector with innovative solutions.

5. Recommendations

While the TALOS-TWO project is an effective effort to centralise EU resources, share notes, and regionalise HEL supply chains, the right public policies can further reduce redundancies, involve more practitioners in the innovation process, and crowd-in the HEL sector in a budget-constrained environment.

5.1 *Increase participation in dialogue and communication fora to share lessons and findings*

The EU should create a central forum for all HEL manufacturers to discuss development efforts and share lessons. There are several aspects of low-power HELs, such as efficient pumping and thermal management, that may apply to high-power HELs, and vice-versa (such as advanced cooling). For example, scientists and engineers involved in creating low-powered c-UAS HELs for Italy's Navy in the MBDA-Leonardo project can discuss their efforts with engineers involved in TALOS-TWO, if they are not already sharing their findings across various players in the supply chain. Secondly, more EU countries – especially those with HEL expertise – should join Spain's and Italy's PESCO effort to develop a 10kW HEL. These efforts would enable better knowledge transfer, reduce redundancies, and increase interoperability.

5.2 *Ease procurement rules to allow rapid deployment with a minimum viable product*

The UK can deploy its DragonFire HEL by 2027 because of a change to its Defence Ministry's procurement rules. Previous rules demanded that a fully viable product be delivered to the military, while new rules only require that a minimum viable product be delivered (Shapps, 2024). Under this process, practitioners could also offer their feedback on HELs, ensuring fit-for-purpose development. The EU should follow in the UK's footsteps and consider deploying workable HELs into the field quickly. This would similarly allow HEL manufacturers to continue the final stages of development in the field, ensuring that the weapon is fine-tuned based on feedback from active units and is fit-for-purpose.

5.3 *Include HELs into NATO's DIANA*

NATO should include HELs as a priority area in its DIANA accelerator. This would help to crowd in small to medium-scale private sector companies who might be able to develop small but powerful solutions to problems that bigger Multi-National Corporations might be facing in their HEL development. Smaller players could also partner with larger companies or join ongoing consortia to strengthen the regionalisation of domestic HEL production and provide novel solutions.

6. Conclusion

HELs are a useful and powerful innovation that provide c-UAS and c-RAM abilities, especially as drones compel doctrinal changes in land warfare and are new weapons for non-state actors. HELs can also alter strategic calculations in MAD scenarios, as they could provide a reliable defence against a first strike. However, there are technical challenges in this process. Line of sight requirements, beam strength, and thermal considerations currently limit HELs' usefulness and scalability. More should be done to address these challenges because Europe should maintain its strategic and tactical edge against its adversaries, non-state actors and otherwise. European players can centralise efforts and share information across the supply chain and with practitioners, so that various scientists, engineers, and innovators across the HEL supply chain can share information. Procurement laws should be modified so that militaries can start to benefit from HELs while contributing to a fit-for-purpose development. Finally, NATO and other European players can crowd-in the HEL sector by including HELs as a priority area within its DIANA accelerator, bringing small-scale private solutions that may help larger consortia with problems. This way, Europe would be able to address current technological issues and maintain its strategic and tactical edge against its adversaries.

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