THE ECOLOGICAL BOOTPRINT OF UK MILITARY DIGITALISATION

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Executive summary

The UK, like many other states, is undergoing drastic transformation towards a digital-age military power. Military digitalisation is often discussed primarily through questions of strategic autonomy, security governance or the laws and ethics of war. In addition, this briefing demonstrates that the advancement of digital systems and services for UK and other militaries hinges on extensive global digital hardware supply chains and infrastructure networks that reshape landscapes, consume life-affirming resources and spawn toxic wastes which degrade human and environmental health alike. The briefing maps the localised though globally reaching lifecycle impacts of the UK military's updating into a 'digital force' reliant on data-centric, cloud-supported, AI-enabled and autonomous military weapon and command-and-control systems.

Providing an indicative summary of the ecological 'bootprint' of UK military digitalisation, the briefing highlights four primary findings related to toxic supply chains with unequal industrial versus household burdens and benefits; increased war-related destruction; unviable resource demands; and lack of publicly available data. In effect, the digitalisation of armed forces pertaining to a single nation like the UK depends upon linked yet globally dispersed geographies made hazardous to human and environmental health by raw material extraction, component manufacturing, computing infrastructure, and the development, deployment and disposal of digital-age weaponry. Autonomous weapon development in the UK is therefore linked with the generation of detrimental social and ecological conditions that stretch from data centres along the UK's urban fringes to mines in Indonesia and the Democratic Republic of Congo, semiconductor fabrication factories in Taiwan, computing and communications networks across Europe and the US, wars in Ukraine, Iran and Palestine, and e-waste scrapyards in Ghana. Common across these four political-geographic categories of extraction, manufacturing, computation and war, are patterns of resource capture, ecosystem destruction, habitat decline, poisoning of animals and plants, and public health deterioration.

By drawing together digital war's lifecycle impacts, the briefing draws attention to how military digitalisation in general, and autonomous weapon systems in particular, are implicated in a global continuum of bodily and ecological degradation, whereby certain lives and lived environments are made insecure so as to secure the late-modernisation of the British military and its lethal capabilities. Faced with the rapid scaling of military digitalisation and the acceleration of associated toxic waste streams and energy, water, land and mineral demands, it is crucial that we draw on existing evidence to indicate the types and degrees of harm thereby anticipated. This will be essential for our chances to regulate and, at best, prohibit the unhinged digitalisation of weapons, war and warfighters before the harms outlined in this briefing become unavoidable or irreversible.

Key findings

1. Military digitalisation in and beyond the UK is deeply embedded in energy-, resource- and waste-intensive material supply chains with detrimental up-, mid- and downstream impacts on human and environmental health. These impacts can be divided into three areas of particular harm, including: a) the diversion of life-affirming resources such as

electricity, water and land or property from local inhabitants to industrial development projects; b) widespread and large-scale toxification of air, water and soil resulting in cancers, failing organs and chronic illness, alongside poisoning of animals and plants; and c) the loss or fragmentation of avian, marine and terrestrial habitats.

2. The growing use of autonomous weapons and AI-enabled targeting systems is not only increasing the scale of civilian dead and injured, but also that of infrastructural and environmental destruction, thus expanding the toxic pollution, carbon emissions and ecosystem degradation associated with military operations. This is exemplified by recent and ongoing operations in Ukraine, Palestine and Iran, in which the UK is in/directly implicated because of its reliance on multinational commercial data and tech providers – specifically Amazon Web Services, Google, Microsoft, Oracle and Palantir – to scale and implement UK Digital Defence services.
3. The expansion of digital services with military applications in and beyond the UK exacerbates global resource pressures – foremost minerals, water and energy – beyond viable social and biophysical limits. UK military digitalisation thereby contributes to the impossibility of global climate and ecological remediation, while misappropriating resources required for just transitions. In consequence, life-affirming resources are directed away from a socio-ecologically sound global economy, towards a global economy of high-technological war and capital concentration.
4. Digital (and) military supply chains are marked by increasing dispersal, complexity and opacity, which means that the lifecycles of digital military technologies, hardware and infrastructure are poorly understood. The lack and withholding of publicly available data on the resource use and pollution profiles (material metabolism) of the UK MOD, and its myriad suppliers, therefore constitutes a threat to ecological health in its own right.

Case study headlines

The expansion of UK Digital Defence capabilities, which underpin the development and use of AI-enabled and autonomous weapon systems, can be linked with:

- The growing power and vast ecological impact of global technology corporations such as Microsoft, Amazon, Google, Oracle, Palantir, TSMC, Intel and Nvidia, whose cloud platforms, data infrastructure and component hardware increasingly underpin military decision-making and warfighting capabilities.
- The expansion of data centres in and around Greater London, which exacerbate urban ‘data heat islands’ alongside inequalities in housing, electricity and water access and costs, as seen in Slough and West London; and drive the loss of greenbelt land and nature-rich habitats, from North Ockendon to Arena Essex.
- The increase in carbon emissions from natural gas and other fossil fuel consumption as UK data centres struggle to meet ever-growing electricity demands and turn to off-grid hydrocarbon generators (primarily natural gas).
- Water stress, pollution risks and the prioritisation of semiconductor production over local livelihoods and marine habitats in Taiwan’s chip-manufacturing regions.

- Toxic mining conditions, chronic illness, habitat destruction and labour exploitation across the copper, cobalt and coltan extraction zones of the Democratic Republic of Congo.
- Deforestation, biodiversity loss, air pollution and the dispossession of Indigenous and coastal communities in Indonesia's archipelagic nickel-mining boom regions.
- Hazardous electronic waste processing, toxic pollution and chronic health impacts in Ghana's e-waste scrapyards, where discarded digital (and) military technologies are dismantled, burned or melted in chemical baths.
- Oil-facility fires, toxic atmospheric fallout, carbon emissions and long-term environmental contamination associated with AI-enabled targeting operations in Iran.
- Landscape contamination, biodiversity decline and the accumulation of military debris from increasingly digitalised and drone-intensive warfare in Ukraine.
- The large-scale destruction of homes, farms, water infrastructure and ecosystems in Palestine, intensified through AI-enabled targeting systems reliant on cloud computing infrastructure.

Introduction

Advanced autonomous weapon systems (AWS) have been integral to the conduct of contemporary war among NATO members for more than three decades. Particular technologies such as semi-autonomous drones, "smart" bombs and remote sensing through satellite and geospatial intelligence (GIS) feeds, have come to define the current era of "latemodern war," which refers to the capital- and technology-intensive approaches to military equipment and operations advancing especially since the 1990s (Gregory 2011; Griffiths and Redwood 2024). In the past ten years or so, this warfighting paradigm has been further transformed by the rapid and large-scale development of *military digitalisation*. For the purposes of this briefing, I use the umbrella term of 'military digitalisation' to capture the accelerating integration of artificial intelligence (AI), robotics and autonomous systems (RAS), machine learning (ML), cloud and quantum computing, data and sensor fusion networks, and digital command-and-control (C2) systems into military organisations and operations (Burilkov et al. 2025).

This latemodern era of high-technological weapons and warfighters is presumed to have resulted in a more "human" and "ethical," even "humanitarian," mode of war (Schwarz 2025; Zehfuss 2018). AI-enabled targeting software, networked sensor systems (fusing cloud, satellite and in-field data streams), quantum-driven inertial navigation and guided munitions are all supposed to increase and ensure the "precision" targeting and "surgical" strikes of contemporary operations, mitigating against the inevitability of human error (for critiques of this premise, see: Arentze et al. 2026; Gvaryahu 2026; Moffett 2026). In addition, though less widely known, digitalised warfare – including precision weaponry – is also often presented as less environmentally destructive (DSTL UK 2024a; 2024b; Edwards 2026b); and we often think of digital services, such as cloud-based or AI-enabled software, indeed as 'virtual' or somehow immaterial, and therefore as less of a burden on biophysical systems (Monserrate 2022). In reality, however, military digitalisation is entirely dependent on, and embedded in, catastrophic material conditions with demonstrably imprecise, negative impacts on human and environmental

health that stretch across geographies and generations, leaving toxic traces that precede and succeed what we consider 'war-time' or the 'battlefield'.

In this briefing, I address the oft-overlooked material embeddedness of military digitalisation by tracing the ecological impacts of digitalised military technologies before, during and after deployment. This includes paying attention to ecological harm generated across the material lifecycles of such technologies and their attendant infrastructures; from the extraction of their base-material sources, across their component supply chains, through their use in and disposal after military operations[1]. The briefing focuses in particular on the UK's military sector[2], while also drawing on examples – such as of the ecological fallout of algorithmic warfare – from beyond the UK to offer an ecological argument against war's growing digitalisation, including the innovation, scaling and fielding of lethal autonomous weapon systems (LAWS). The UK Ministry of Defence (MOD) and Armed Forces are currently accelerating their digital development, captured by a series of policies such as the Digital Strategy for Defence; Digital MOD; the Cloud Strategic Roadmap for Defence; and the Defence AI Strategy and Centre (see UK GOV n.d.; UK MOD 2023; 2022; 2021; n.d.).[3] Together, these policies form the Digital Backbone of British Defence, identifying AI and "cloud-first" approaches as central to future military capabilities and outlining key priorities in the form of hyperscale cloud computing capabilities, data and domain interoperability, autonomous vehicles and logistics, human-machine teaming, battlefield analytics, targeting systems, and synthetic training environments. By example, through Project THEIA – part of the MOD's "greener" Future Force programmes – the British Army is "marching to the beat of digital transformation," en route to becoming "an information-age-ready army" with a "data-centric" approach to warfare (British Army 2023a, 3, 7; 2023b). Such an army has widely adopted RAS, AI and ML functions to map, analyse and act on operational environments.

Crucial here is to recognise that the advancement of military digitalisation is an ongoing process where the promises of functions such as cloud-based, networked, AI-enabled or autonomous military systems, and the technological and infrastructural expansion required for their realisation, are still under development. Equally crucial to recognise is the fact that the UK MOD – like most military sectors – still largely relies on adapting and adopting digital services innovated by commercial actors, foremost multinational Big Data, Tech and Business corporations like Google, Microsoft and Amazon Web Services (AWS). The digital hardware and infrastructure on which war's digitalisation hinges are often shared across military and commercial sectors, such as semiconductor devices from Taiwan Semiconductor Manufacturing Company (TSMC) and Nvidia. This deepening commercial-military intersection explains the growing concern with, by example, data centres, semiconductor supplies and subsea telecommunications cables, as 'strategic' dual-use assets. In consequence, we cannot yet assess the full direct impact of *military* digitalisation on human and environmental health, or on ecological systems and biodiversity. However, while much remains hypothetical in terms of the precise effects of digitalised military applications, a substantial body of evidence already

[1] Many emerging technologies never reach the battle/field; for a critique of UK procurement practices see Rogaly (2023).
[2] For a definition of 'military sector' see Edwards (2026a, 19-21).
[3] For critiques of UK military AI policy, see Burt (2022; 2021; 2018).

documents the ecological impacts of digitalisation and artificial intelligence applied across civil and commercial sectors; that is, the impacts of societal digitalisation writ large (see e.g. KTH 2026; Sovacool et al. 2022; UNCTAD 2024; Vrana and Singh 2026). This evidence underwrites our enquiry into the planetary costs of digitalised war and serves as a crucial springboard for what harms to expect from, and which questions to ask of, the rapid scaling thereof.

Tracing the ecological 'bootprint' of military digitalisation, the briefing highlights four primary findings. Firstly, military digitalisation is deeply embedded in energy-, resource- and waste-intensive material supply chains with detrimental up-, mid- and downstream impacts on human and environmental health. These impacts include widespread and large-scale toxification of air, water and soil resulting in cancers, failing organs and chronic illness, alongside habitat decline and the poisoning of animals and plants. Secondly, the growing use of autonomous weapons and AI-enabled targeting systems is not only increasing the scale of civilian dead and injured, but also that of infrastructural and environmental destruction, thus expanding the toxic pollution, carbon emissions and ecosystem degradation associated with military operations. This is exemplified by recent and ongoing operations in Ukraine, Palestine and Iran. Thirdly, the expansion of digital services with military applications in and beyond the UK exacerbates global resource pressures – foremost minerals, water and energy – beyond viable biophysical limits. UK military digitalisation thereby contributes to the impossibility of global climate and ecological remediation, while misappropriating resources required for just transitions, directing them away from a socio-ecologically sound global economy, towards a global economy of high-technological war. Fourth and finally, digital (and) military supply chains are marked by increasing dispersal, complexity and opacity, which means that the lifecycles of digital military technologies, hardware and infrastructure are poorly understood. The lack, and often active obstruction, of publicly available data on the resource use and pollution profiles (material metabolism) of the UK MOD, and its myriad suppliers, therefore constitutes a threat to ecological health in its own right. These findings build towards the argument that the growing development and use of digitalised and variously automated military technologies constitute vast and as-of-yet untold sources of resource capture, ecosystem destruction and health deterioration that compound across the technological and infrastructural lifecycles of military digitalisation, severely undermining the prospects of mitigating climate and ecological crises in the UK as well as globally.

The briefing traces these impacts and builds this argument across three sections. Section one outlines the resource appetite, and exemplifies the localised impacts of, two key material conditions pertaining to digital war's *ecological 'beforemaths'*: digital supply chains (minerals and component hardware); and digital infrastructure (computation). Section two turns to impacts generated during the deployment and disposal of digitalised force, offering indicative examples of its *ecological 'aftermaths*.' Section three hones in on the particular issue of biodiversity loss. Together, the three sections map military digitalisation across four political-geographic categories: extraction; computation; manufacturing; and war. To conclude the briefing, I highlight existing evidence-gaps and suggest further avenues of inquiry with which to hold state, corporate and military stakeholders to account for the ecological impacts of military digitalisation in the UK and beyond.

1. Ecological beforemaths: Impacts of digital infrastructures and supply chains

It is useful to think of the ecological impacts of military digitalisation as threefold to distinguish between, while recognising the links across, impacts generated *during*, *after* and *before* the deployment of a particular cloud-based, AI-enabled or autonomous military system. By tracing these impacts down- and upstream from particular sites of deployment we can capture the full ecological *bootprint* of military digitalisation. Bootprint is here borrowed from Stuart Parkinson's use of toeprint, footprint and bootprint as measuring criteria for military carbon emissions, where an analysis of a military's climate – or, for the purposes of this briefing, ecological – *boot*print not only includes the direct impacts of maintaining and training military bases and troops, but also the full range of climate and ecological impacts generated during and after military operations as well as across the technological and raw-material supply chains on which military activities rely (Parkinson 2025, 6).

As demonstrated in this section, digital technologies, component hardware and infrastructure consume vast quantities of material resources – foremost minerals, land, energy (electrical power) and water – and this consumption is particularly felt by the globally dispersed communities and ecosystems where these resources are extracted, processed, seized, misappropriated, and disposed of (see e.g. Arce 2014; Bresnihan and Brodie 2025; Deberdt et al. 2025; Rubaii and Griffiths 2025; Sovacool 2019). In this sense, military digitalisation should be thought of as a 'doubly destructive' business (Górska and Griffiths 2026) that generates social and ecological harm that also precedes and succeeds digitalised military technologies' direct use. To appreciate the full ecological impacts of such technologies we therefore need to pay as much attention to their ecological 'beforemaths' as to their human and environmental 'aftermaths' (Griffiths and Rubaii 2024).

To simplify the task of exemplifying these before- and aftermaths, I focus throughout the briefing on two technological streams prioritised in the UK MOD's Defence Digital, Data and AI strategies: AI-enabled autonomous aerial and ground vehicles; and AI-enabled C2 systems. Banking on the innovation and adoption of such technologies, the Defence AI Strategy (UK MOD 2022, 1) invites us to "imagine" an idealised vision of the future of British warfare in which frontline soldiers, trained in highly-developed synthetic environments, are guided in real-time by portable C2 devices fed by cloud databases which capture, process and fuse hundreds of hours of footage and thousands of data points from cameras, satellites, radars and other sensors. Further, the soldiers are backed by swarms of autonomous surveillance drones and precision loitering munitions, alongside uncrewed combat vehicles and navy vessels carrying next-generation armaments, such as Directed Energy Weapons that use lightning-fast target detection algorithms, all backed by the MOD's AI-enabled Digital Backbone (UK MOD 2022, 1).

Examples currently in use by UK armed forces or under development by UK-affiliated agencies and arms companies include Rheinmetall's (2026) HX2 and BAE System's (2026) ATLAS uncrewed supply and combat tanks; Innovaero's OWL family of loitering munitions (BAE Systems 2025); the Defence Science and Technology Laboratory's (DSTL UK 2026) Swarm Capability Test Bed; and the Royal Air Force's StormShroud uncrewed combat drone (UK RAF 2025). In 2026, the UK MOD also opened Europe's largest-ever drone development, testing and

training centre in Swindon, southwest England (UK MOD 2026). Finally, of great relevance here are the UK MOD's Digital Backbone projects, that, next to the internal MODCloud service, include infrastructure and services provided by commercial giants AWS, Microsoft Azure, Oracle Cloud, Google Cloud (owned by Alphabet Inc.) and Palantir, all of which underpin the British Armed Forces' on- and off-base C2 systems (UK MOD n.d.; 2023). Together, these companies – all with controversial roles in global military, economic and ecological crises – are crucial enablers of the UK MOD's implementation of its Defence Digital, Data and AI strategies, "helping transform MOD into a truly data-centric organisation where every soldier, analyst, and commander can seamlessly access and exploit data" (UK MOD 2025).

The material implications of this warfare vision involves a wide range of minerals, component hardware, and infrastructure, all of which require highly polluting and land-, water-, chemical- and energy-intensive extraction, processing and manufacturing conditions. In effect, then, the development and scaling of digital military technologies for the British Armed Forces is dependent on increasingly complex and globally integrated hardware supply chains and infrastructure networks with unevenly distributed negative impacts, all of which come together to constitute digital war's *ecological beforemaths*. Table 1 at the end of this briefing (page 30) illustrates the type, spread and effects of this dependency, focusing on minerals and their extraction. A useful typology to trace these beforemaths (ecological impacts and relations) is to think through military digitalisation across three political-geographic categories: extraction, manufacturing, and computation. In what remains of this first section, I exemplify impacts associated with each of these geographies, focusing on mineral extraction; semiconductor manufacturing; and the expansion of computing capabilities in the form of data centres.

Extraction geographies: minerals and metals

Advanced military technologies have a voracious appetite for minerals and metals, which increases alongside the growing sophistication of their digital functions. As detailed by Griffiths and Rubaii (2024, 9):

> … late modern forms of war depend entirely on elements of the Earth's crust: metals such as copper (wiring), nickel-chromium (resistors), lead and tin (solder), as well as the crucial metalloids silicon and germanium (for transistors). Without these minerals there would be no electronics in military hardware (or anywhere).

While "volumetrically minor" these mineral elements are still "functionally essential" to the development and deployment of the UK's digital warfighting paradigm (Griffiths and Rubaii 2024, 9). By way of an indicative list, AI-enabled autonomous aerial and ground vehicles require aluminium, titanium and magnesium for fuselages; lithium, cobalt, nickel and graphite for batteries; rare earth magnates for propulsion; silicon, gallium, germanium, boron, phosphorus and arsenic for semiconductors, microchips and processors; and tantalum, tungsten and gold for memory chips and data storage (see Figure 1 at the end of the briefing, page 32; see also SFA Oxford n.d.). Many of these components and their mineral makeup are also used for the small- to largescale hardware required by AI-enabled C2 systems, where, by example, copper, nickel, aluminium, platinum, silicon, gallium, germanium, silver, tin, tantalum and rare earths are

especially important to the data storage, networking, advanced computing, cooling and power functions of data centres, cloud infrastructure and subsea fibre-optic telecommunications cables (see Figure 2 at the end of this briefing, page 33; see also MRP 2025).

Though already spectacular, the mineral and metal demands of both advanced military and digital technologies are projected to increase drastically, further compounded by energy transition mineral needs (see Edwards 2026b, 7). Global mineral demand for lower-carbon energy technologies is expected to quadruple by 2040, while the combined consumption of lithium, graphite, nickel and cobalt by energy transition, defence, electronics and other growth sectors, is expected to double (IEA 2021). Cobalt is often derived as a byproduct of copper and nickel mining. In the UK alone, copper demand will rise with 200% and lithium with 1100% already by 2035 (UK GOV 2025). Expansion of data centre capacity is a key contributor to this rise as centres' material intensity increase with the rise in AI-dedicated facilities to account for "higher rack densities, heavier electrical backbones and more robust cooling" (Hulak and Allgood 2025). Each megawatt of regular-size data centre output is estimated to consume around 60-75 tonnes of minerals, foremost for power and cooling, of which copper alone can account for 27 tonnes depending on the data centre size. A single present-day *hyperscale* AI data centre, however, can use up to 50 000 tonnes of copper, such as Microsoft's AI accelerator facility in Gävle, Sweden. Estimates suggest that the data centre demand for copper globally could grow six-fold, to reach around 3 million tonnes per year by 2050 – roughly equivalent to the combined yearly output of today's four largest copper mines (BHP 2025).

Of essence to our study here is that all of these minerals and metals are obtained through long and opaque supply chains, often purveyed by mining giants listed on the London Stock Exchange with considerable colonial historical baggage, like BHP Group, Anglo American, Rio Tinto and Glencore (Selwyn 2020). All elements' root sources can then be traced back – via myriad resource-intensive smelters, processing plants and refineries – to so-called extractive 'sacrifice zones' especially found in the Global South, though also North (see EJ Atlas 2026). Industrial-scale mining, whether using surface, underground, in-situ or dredging methods, necessitates large-scale clearing or disruption of landscapes and waterbeds, and the use of cyanide, mercury and arsenic to separate usable minerals and metals from the extracted ores (rocks), brines or sandbeds. These processes generate vast quantities of surplus source-materials as well as so-called 'mine tailings': a slurry-type waste containing toxic heavy metals, metalloids, processing chemicals and acid-generating minerals. Besides running directly into local water sources, tailings are most commonly stored as wet slurry in engineered, large-scale and failure-prone reservoir dams.

London Mining Network estimates that the global mining industry generates 13 billion tonnes of mine tailings per year (with a 5% annual increase) and that there are 8100 tailings dams globally, 3400 of which are active. These dam infrastructures are supposedly built to store toxic tailings in perpetuity, thereby constituting both daily and long-term threats to local and downstream populations and ecosystems. Threats include small- to large-scale dam failures such as seepage, overtopping, pipe erosion, slope failure and unrehabilitated legacy dams (LMN 2026). Next to a large number of un/known smaller incidents, at least 11 cases of catastrophic dam failures releasing more than one million cubic metres of tailings were

documented between 1998 and 2022. The most severe failures occurred in Brazil, Canada, the Philippines, South Africa and Spain. In addition to ecological degradation, mineral extraction and processing is also marked by conditions of socio-economic vulnerability where elite networks – often coalitions of multinational mining corporations, state actors, private security companies and/or paramilitary groups – exploit workers, threaten local communities and deploy a range of tactics to deter resistance to extractive activities, including armed violence (Dunlap 2019; Selwyn 2020).

For an example of the localised impacts of mining in/directly tied with UK military digitalisation, see *Case study box I* on nickel extraction in Indonesia below (pages 11-13). Similar conditions mark the extraction of copper – an absolutely essential element to all digital and military hardware of interest to this report, "none of which would function without copper's conductive properties" (Griffiths and Rubaii 2025, 9). A majority of global copper – and its byproduct, cobalt – is mined at enormous human and environmental costs along the Democratic Republic of Congo's (DRC) so-called copper belt. Holding 10% of the planet's copper, and more than a third of its cobalt, the belt reaches through the south of the DRC into Northen Zambia. Along the belt's extractive zones, exemplified by the vast 25 km^2 Musonoi mine nearby the regional capital of Kolwezi, miners, traders and surrounding communities – family members, hospitality staff, sex workers – co-exist with heavy metals accumulating over decades of extractive processes (Griffiths and Rubaii 2025, 12; Sovacool et al. 2020, 8-10). Long-term exposure to cobalt, arsenic and uranium causes chronic illnesses, including cancers, heart and kidney disease, DNA damage, stillbirths and birth defects. Both corporate and individual ('artisanal') miners are forced through back-breaking labour under potentially lethal working conditions. Over the years, hundreds of miners, including children, have been buried by collapsing mine walls or failing infrastructure.

Importantly, the deterioration of human health along the copper-belt is directly linked with the degradation of the environment, where mines, mining tunnels, trading depots, processing stations and tailings disposal sites encroach upon forests and habitats, toxify rivers and wetlands, erode the soil and coat entire mining areas in hazardous dusts. In Eastern DRC, human and environmental health is equally degraded by the large-scale mining of coltan, another essential mineral element in military and commercial electronics which refines into tantalum. Although minerals sourced from the DRC are supposedly protected by international regulation on 'conflict minerals', vast quantities of copper, cobalt and tantalum nevertheless travel through strategically opaque supply chains to reach multinational tech giants like AWS and Microsoft as well as UK-based arms producers like BAE Systems (see e.g. Rubaii et al. 2025).

In sum, military digitalisation relies on the continuation and expansion of global conditions of mineral extraction marked as much by the depletion and degradation of air, water and soil, as by affected communities' exposure to social, economic and armed forms of violence.

Case study box I: Nickel extraction in Indonesia

Nickel is considered a critical strategic metal of increasing importance to the technologies and services that make up the UK's Digital Defence strategies, such as AI-enabled drones, autonomous vehicles, and on- and off-base command-and-control systems operating through cloud platforms. In combination with other elements, the metal is prized for its high-temperature endurance, resistance to corrosion and utility in specialised alloys and coatings, widely used in rechargeable batteries, advanced vehicle frames, hardware housing that shield AI and sensor payloads, and for electrical circuitry. The Vale Base Metals refinery in Clydach, Wales – the UK's only nickel refinery and Europe's largest – processes nickel into high-purity class 1 battery-grade nickel essential for aerospace and defence, as well as electronic hardware components, sold both to domestic UK and international markets (UK GOV 2025). Much of this nickel is originally sourced, via processing facilities in Canada and Japan, from mines and smelters in Indonesia. While neither the UK MOD nor most of its tech and weapons suppliers publicly disclose their mineral supply chains, it is probable that Indonesian nickel finds its way into digital military technologies and services deployed by the British military via midstream processing plants like Clydach or via other contractors operating on the London Metal Exchange (EIA 2026).

Nickel extraction in Indonesia is directly implicated with the devastation of local ecosystems and living conditions. Growing nickel demand is currently causing a shift from sulphide ores mostly mined in Australia, Canada and Russia, towards so-called lower grade laterite ores abundant in the topsoil of tropical regions, thereby expanding mining frontiers in formerly colonised countries across South Asia, foremost Indonesia. The processing of laterite nickel ore reserves often requires energy- and land-intensive open-pit or strip-mining methods. Given that only about 1% of extracted material contains nickel, these mining methods leave behind large quantities of waste overburden. Across affected geographies, nickel extraction is therefore associated with increasing carbon pollution, deforestation (especially of rainforests), water depletion and environmental contamination, alongside large-scale dispossession of local communities, Indigenous rights violations and violence against environmental defenders (see Andreucci et al. 2023).

On the Indonesian islands of Sulawesi and North Maluku, the 'nickel boom' has transformed once-small majority Indigenous villages into hubs for the world's largest open-pit nickel mine projects. In North Maluku, Indigenous Hongana Manyawa communities struggle to meet their food needs as mines eat away at their forests (EIA 2026), while coastal fishing communities in Sulawesi are forced to live amid open mines, deforested hills and exposed red dirt with leaching acid mine drainage (Hanzhang Jin 2026). In Sulawesi, fossil fuel heavy extraction and smelting activities have tripled the region's electricity consumption, competing with local household needs while causing a drastic increase in carbon emissions and particulate air pollution. Across both islands, respiratory illnesses have risen sharply, with workers and nearby residents inhaling toxic dust, fumes and emissions on a daily basis (Sawal and Adiningsih 2026). Deaths and injuries from workplace accidents are also widespread, in

addition to the prosecution of people resisting or investigating harms from nickel extraction projects.

Furthermore, at least 80 000 hectares of rainforest have been destroyed across both islands, and another 500 000 hectares are at risk of clearing for laterite extraction and ferronickel or nickel pig iron smelting (EIA 2026). These rainforests are especially rich in ecosystem and habitat variation, with unique endemic species evolving over millions of years isolated from large-scale human development, such as the Sulawesi bear cuscus. Besides forest destruction, tailings from nickel ore extraction and smelting also damage marine diversity throughout the Indonesian archipelago, such as threatening the already endangered 'kima,' or giant clam, endemic to the coast of Sulawesi (Hanzhang Jin 2026).

Manufacturing geographies: semiconductor microelectronics

Digital military technologies depend upon a number of component hardware, crucial among which are various forms of microelectronic semiconductor devices, often grouped under the umbrella terms of 'microchips' or 'semiconductors'. Key examples include micro- and memory chips, AI accelerators, and central and graphics processing units (CPUs and GPUs). Microchips are considered the brains of modern-day electronics and digital infrastructure – both drones and data centres – and they operate thanks to ultra-processed semiconductor elements or compounds like silicon, diamond and germanium, or gallium arsenide and silicon carbide, which conduct or block electricity flows in controlled and designated ways. Indispensable to everything from smartphones, laptops and solar panels to satellite and fibre-optic communication networks, semiconductor devices have also become "the indispensable foundation of modern defence capability" upon which depend "every advanced military system, from combat aircraft and missiles to autonomous platforms, radar, electronic warfare and secure communications" (UK S-APPG 2026, 4).

Confirming their centrality to the digitalisation of UK warfighting capabilities, the UK All-Party Parliamentary Group for Semiconductors note that "as warfare becomes more digital, autonomous and data-driven, the importance of trusted semiconductors will continue to grow" (UK S-APPG 2026, 4). Different semiconductor devices perform different functions for this warfare paradigm: CPUs ensure general-purpose computing tasks and systems management, while GPUs and specialised AI accelerators perform the parallel computing tasks of AI model training, machine learning, and large-scale data analytics which enable real-time target recognition and sensor fusion functions. Further, application-specific integrated circuits (ASICs) perform high-speed mission-specific tasks like munition guidance or autonomous navigation. These processing chips are further complemented by memory, storage and communications chips.

Like most digital and military systems, microchips and semiconductor components travel through thousands of production stages, along intricate and disaggregated global supply chains from source to end product. The UK has a small though significant domestic semiconductor market, focused on design and manufacturing of compound semiconductors such as gallium

nitride or gallium arsenide, and indium phosphide devices which all underpin the use of radars, electronic warfare suites, and satellite and secure communications in military operations. In 2024, the UK MOD spent £27 million on the acquisition of a gallium arsenide factory in Newton Aycliffe, County Durham, with another £200 million to be invested over time to directly boost British semiconductor capacity with military applications (UK S-APPG 2026, 7). Though the UK does not intend to compete with the large-scale either raw silicon or compound semiconductor (wafer) manufacturing capacities of countries such as China, Russia, Brazil, the US, Taiwan and South Korea, this domestic market is nonetheless projected to grow, as outlined in the UK Semiconductor Strategy (UK GOV 2023). A majority of the semiconductor devices built into UK digital military capability, however, are supplied by major global information technology (IT) corporations like TSMC (Taiwan), Intel (US), Nvidia (US), AMD (US), and Global Foundries (Europe) often reaching the UK MOD via big tech players like AWS, Microsoft and Google, who design their own chips for use in computing, cloud and data centre services. While the US and Europe dominate on chip design and production of specialised equipment, semiconductor manufacturing happens mostly in fabrication factories and foundries (so-called 'fabs') concentrated in East Asia, particularly Taiwan, which accounts for the majority of global advanced microchip fabrication capacity.

Pinballing across the US, Europe and East Asia, the global journeys of microchip assembly are marked by the misappropriation of money, water and energy as well as spread of toxic chemical products and wastes. In terms of money, a single leading-edge chip can cost $50-100 million to design; $100 million to manufacture; and $20 billion to build the manufacturing plant (McKeown 2025). The material intensity of chips is equally great. Though the quantities of minerals used for each semiconductor device are not large, the number of devices produced globally (over 1 trillion per year) and required for functions such as AI model training (requiring up to 8000 GPUs per large-scale language model), compound their contribution to global mineral and metal demands. By example, a study by Falk et al. (2026) finds that artificial intelligence hardware, exemplified by the number of graphics processing units required for training and deployment, consists of 90% heavy metals. Common GPUs, such as the Nvidia Ampere (A100) used to train large AI models, contain 32 mineral elements, foremost copper, iron and tin, alongside silicon, nickel, aluminium and chromium, and smaller amounts of magnesium, boron, palladium and silver (Falk et al. 2026, 3). These raw material requirements connect microchip development with the detrimental social and ecological effects of mining, as detailed above, such as in the context of nickel and copper mining in Indonesia and the DRC. In addition, the elements used for compound semiconductors, gallium and germanium, are produced as byproducts of zinc or bauxite (aluminium ore) processing, 80% of which is manufactured in China. Bauxite mining has a particularly large environmental footprint such as from water consumption and the generation of red mud wastes (Hess 2024; Zeng et al. 2020). In contrast, silicon is extracted from sand – Earth's most abundant element – before being processed through energy-intensive forms of heating into the ultra-pure metallurgical-grade materials used for semiconductor wafers.

In addition to extraction geographies, the production of a single chip – such as the Nvidia Blackwell, Hopper or Ampere GPUs used for Microsoft Azure data centres, or the Nvidia Jetson

Orin family's edge AI accelerators which give drones on-board AI capacities – involves a global network of manufacturing geographies (see Figures 3-5 at the end of this briefing, pages 34-35). These geographies stretch from chemicals, specialty gases and equipment (e.g. ultraviolet lithography) factories in France, Germany and the Netherlands; to front-end manufacturing facilities in Taiwan and South Korea where integrated circuits (or 'dies') are applied to processed semiconductor materials to make the final wafer used for chips; and onwards, to back-end assembly, test and packaging (ATP) manufacturing facilities also in Taiwan, or in Malaysia, China and the US, where dies are separated from the wafers and integrated with their final chip packages in a more manual and less resource-intensive process.

Apart from the significant local alongside total supply chain impacts of heavy equipment and chemical manufacturing, semiconductor devices' heaviest ecological impact occurs at front-end manufacturing fabs. Semiconductor fabs are some of the most resource-intensive industrial facilities in the world, at times spanning almost 100 000 square metres. Manufacturing requires more than 50 types of specialised equipment, such as for deposition, lithography and etching, and 300 often highly toxic chemical compounds, including fluorinated gases and forever chemicals (such as per- and polyfluoroalkyl substances or PFAS), which are applied through over 1000 process steps (Hess 2024). Many of these gases, which often escape factories to settle in the atmosphere, have heating effects 23,500 times higher than carbon dioxide.

A single front-end fab can consume as much energy as a mid-sized city in order to ensure the 24/7 operation of vacuum chambers, plasma etchers, and temperature-stable cleanrooms; the electricity for which is often sourced from fossil fuels, such as coal and natural gas in the case of Taiwan (Grover 2025). A large fab can use up to 38 million litres of water per day, equivalent to the daily water consumption of around 300,000 people in Germany or 500, 76 000 litre, swimming pools (Hess 2024). By comparison, this is twice the daily water consumption of an average hyperscale data centre. Most is needed for ultrapure water production – stripped of nearly all ions, particles and microbes – through which every wafer passes for hundreds of cleaning cycles. Each fab also produces large quantities of chemical, ultrapure water and slurry wastes which are either treated and stored on-site or transported to external treatment facilities (before recycling for other industries, as far as possible). All such wastes pose risks from leakage, equipment failure or accidents, including the spread of PFAS compounds. Notably, waste generation from semiconductor front-end manufacturing has more than doubled since 2016. In addition, the global spread of semiconductor value chains also grows the amount of carbon embedded in each device, spanning thousands of kilometres from raw material sourcing in Africa and Asia to design in Europe and the US, and manufacturing in Taiwan. Scope 3 (supply chain) emissions indeed often exceed Scope 1 and 2 combined (Grover 2025; Hess 2024).

As the world's largest hub for front-end fabs, with TSMC alone operating 26 large-scale fabs, Taiwan's semiconductor boom has transformed the island's resource governance amid intensifying climate stress, worsening the unequal distribution of water, energy and land use benefits and burdens between industrial parks and local, often rural, communities. Here, as Justin Kollar (2026, 772) finds, water scarcity exacerbated by climate change "is addressed not by reassessing allocation or moderating consumption, but by engineering new ways to secure

water for [semiconductor] industries." As farmlands subside, aquifers decline and rural livelihoods grow increasingly precarious, water continues to be "transferred, extracted or recycled to sustain semiconductor production" (Kollar 2026, 772). Between 2021 and 2023, rice farmers were forced to stop planting rice because of water shortages, meanwhile fabs kept operating 24/7, leading farmers to feel "sacrificed for the semiconductor industry" (Alexander 2025). Worsening air quality from rising fossil fuel consumption for Taiwan's electronics industries also risks increasing premature deaths and children suffering from asthma (Nesan et al. 2026).

Given the centrality of semiconductor devices to the production and performance of digital military systems, the UK's increasing reliance on AI-driven, autonomous warfighting paradigms feeds directly into the significant monetary, land, water, energy, heavy equipment, chemicals and waste inputs and outputs of semiconductor assembly stretching across continents. Next to a growing demand for front-end manufacturing capacity in East Asia, this expensive, resource-intensive and hazardous hardware lifecycle is also set to increase its imprint on UK local communities and environments as the UK Government and MOD looks to expand its domestic market.

Computing geographies: data centres

Cloud-based and AI-enabled services and functions are made possible thanks to large networks of physical infrastructure that cut across data storage, communications and computing hardware. While these include infrastructure such as subsea telecommunications cables (60 of which make landfall in the UK) and computing facilities with ever-more demanding super- and quantum computers, to exemplify the ecological impact of computing geographies in/directly enabling UK military digitalisation I focus here on extant and emerging data centre networks in and beyond the UK. In essence, data centres are warehouse-like facilities that house the IT equipment upon which hinges almost all digital activity. Since 2024, the UK Government designates data centres as critical national infrastructure – thereby as strategic military sites – which "underpin almost all economic activity and innovation, including the development of AI and other technology, public service delivery [including national security], and how we interact with one another" (Clark et al. 2026).

Though their impacts vary depending on size, function and socio-geographic location, data centres compete directly for the resources required to sustain life and support local communities. Besides their mineral consumption and co-option of many thousands of hectares of land, data centre facilities – like semiconductor fabs – require significant amounts of energy and water, leaving an equally significant carbon footprint. As with their mineral appetite, this consumption is also projected to grow drastically with the growth of AI-tailored centres. As of August 2026, there are 12 259 known data centres in the world, located across 179 countries; however, demand for data centres is expected to triple by 2030 with another $7 trillion already expected in centre investments, $5 of which is earmarked for AI-tailored facilities (Dean 2025). The US has the world's largest data centre capacity consisting of 4767 centres, and US-based 'hyperscalers' – including Amazon, Microsoft and Google, the same companies at the root of the UK's Digital Defence – are expected to account for more than 40% of data centre spending

between 2027 and 2032, with each company already investing around $200 billion a year in centre expansion in and beyond the US.

On average, centres cover around 9000 square metres, though hyperscale centres can be as large as 930 000, thus leaving significant impacts on local landscapes and land use relations, such as AWS and Microsoft Azure hyperscale clusters in the US, UK, Sweden and Ireland. The International Energy Agency estimates that global data centres consumed about 485 terawatt hours of electricity in 2025, roughly equivalent to the electricity consumption of the entire nation of France – or enough electricity to power around 40-50 million average UK households for a year. Depending on their size, centres can draw between 5 megawatts (smaller scale) and 100+ megawatts (hyperscale) of continuous power, that is, energy usage at any given moment. By comparison, 4.6 megawatts of continuous power use is enough to power 4000 average US households (Dean 2025). Water consumption is equally worrying, with data centres increasingly tapping into surface and underground freshwater aquifers to prevent constantly operational hardware like microprocessors, server racks and IT rooms from overheating through water-based cooling. Smaller, more efficient centres like Google's facility in Dublin has a *yearly* consumption rate of around 400 000 litres, while larger centres especially in the US can drink up to 19 million litres of water *per day* (Clark et al. 2026; Yañez-Barnuevo 2025) – roughly corresponding with the water use of towns like Canterbury or Bath, or 130 000 UK residents.

UK facilities are not obliged to disclose their water usage and many operators use waterless or hybrid cooling rather than liquid cooling systems. Nonetheless, estimates suggest that an average facility like the two data centre halls in Blyth, Northumberland, consume around 124 million litres per year when counting both direct (cooling) and indirect (water needed for electricity generation) uses. This translates into the total yearly water consumption of around 2500 UK residents. Even though this water demand is lower than most US examples, the fact remains that data centre expansion is putting increased industrial-scale stress on UK water supplies at a time when severe freshwater pollution and increasing temperatures are already leading to water shortages and rising costs especially for vulnerable households. Furthermore, the use of closed-loop or waterless cooling systems consume much more energy: while drawing less water, such cooling solutions instead increase centres' power demand. This is further exacerbated by the growth of hyperscale AI facilities. Indeed, the amount of land, water, electricity, minerals and other materials gobbled up by data centre infrastructure will increase drastically with the rise and spread of AI services; between 2023 and 2030, AI data centre capacity is expected to grow 33% on average each year, with AI workloads potentially accounting for nearly 70% of total data centre demand by 2030 (Falk et al. 2026). Studies already suggest that "the carbon footprint of AI systems alone could be between 32.6 and 79.7 million tons of CO2 emissions in 2025, while the water footprint could reach 312.5-764.6 billion liters," roughly the same annual carbon footprint as New York City and equivalent to the water footprint of the total global annual consumption of bottled water (de Vries 2023).

With the second largest number of facilities in the world, the UK is Europe's largest data centre market, currently counting 586 centres. 273 of these are clustered in London, foremost in the Slough, Hayes and Park Royal areas of West London which constitute so-called 'cloud

availability zones'. At present, studies estimate that 5.9% of the UK's electricity is consumed by data centres, though this is projected to increase four-fold by 2030 as centre buildout is projected to grow the UK's IT power capacity from 2.9 gigawatts in 2026 to 9.1 gigawatts in 2030 (Booth 2026; Kam 2025). The queue to connect to the UK's national electricity grid grew by 460% in the first half of 2025, compounded by data operators. Housing development in London could be directly affected by this, as new residential buildings compete for grid connection with data centre buildouts.

Indeed, Greenpeace UK warns that the unhinged expansion of AI infrastructure including data centres will offer a lifeline for continued fossil fuel extraction to meet electricity needs; while exacerbating the UK's already significant cost of living crisis, resulting in higher energy bills as local households share the burden of data centre electricity consumption (alongside growing stress on water supplies and bills). Increased fossil fuel use to power data centres is already becoming reality in the UK, as the years-long wait to connect to the national grid is 'forcing' centre operators to integrate off-grid site-specific gas generators not only for emergency but also for permanent supply. Between 2024 and 2026, more than 100 operators put in requests for gas connections amounting to 15 terawatt hours of energy per year, equivalent to almost 5 months of London's power demand (Down 2026). Prospects to meet the UK's clean power or net zero targets are severely undermined by the growing coupling of data centre capacity with fossil fuel use, further exacerbated by AI workloads. As a worrying example, reports suggest that 11 US data centres operated by Meta, OpenAI, Microsoft and xAI, could emit more carbon than the country of Morocco from the use of off-grid gas generators.

Real and potential social and environmental risks posed by data centre expansion in and around Greater London is discussed in *Case study box II* below (pages 18-20). If not taken seriously, these risks and their related policy priorities will force the UK in the same direction as the US and Ireland, where aggressive rural and urban data centre expansion has led to digital infrastructure requirements being pitted against the needs and wellbeing of local residents while AI, cloud and computing services' environmental externalities remain ignored. Serving as foreboding though essential examples, the impacts on local living conditions from AWS data clusters in and around Dublin are well documented (see Bresnihan and Brodie 2025).

Altogether, the fast growth of UK cloud, AI and computing (digital) services is translating into the drastic expansion of UK data centre infrastructure. These infrastructure are forcing a return to fossil fuel use such as natural gas with resulting carbon emissions, while also exacerbating already strained electricity grid, water supply, land use, property and industrial-household planning relations, in and beyond urban centres like London. The digitalisation of British military capabilities is feeding directly into these tensions, further compounding cost of living crises and the unequal distribution of life-affirming resources (like housing, electricity, water, and urban and rural commons), privileging industrial development over local household needs.

Case study box II: Data centre expansion along the UK's urban fringes

Residents and greeneries bearing the brunt of data hyperscaling

Existing and planned Amazon Web Services, Microsoft Azure and Google Cloud data clusters in and around Greater London offer key examples of the risks faced by local communities and ecosystems from data centre expansion. British military digitalisation is implicated with these risks given the UK MOD Digital Defence strategies' reliance on cloud platforms, data centre networks, server farms and processing power provided by said hyperscale operators, in addition to Oracle and Palantir as detailed earlier. The UK MOD recently signed new multi-million contracts with AWS, Microsoft, Google and Oracle, for instance aimed at moving legacy systems to cloud infrastructure, accelerating Defence AI Centre activities and strengthening Digital Skills for Defence. Notably, the MODCloud is an accredited and supported AWS Cloud environment. Given the exceeding difficulty to establish direct links between any one data centre and a particular user's cloud service workload – such as particular branches of the UK MOD or Armed Forces – it is of essence to look at impacts from data clusters such as those around Greater London to anticipate the social and ecological externalities generated by the British military sector's extensive reliance on cloud infrastructure.

The broader West London region is considered the UK's data centre capital, currently housing around half of the UK's operational IT power capacity; the town of Slough alone has more than 40 centres. Concentration in this particular area partly owes to the subsea fibre-optic telecommunications cables which run from North America to make landfall in Cornwall before travelling to London along the M4 motorway corridor, which runs through Slough as well as the West London boroughs of Ealing, Hounslow, and Hillingdon. In the first half of 2026, this data cluster generated 1376 megawatts of operational capacity, making West London Europe's largest market for compute power output, ahead of both Dublin and Frankfurt. Here, major hyperscalers like Microsoft Azure, AWS and Google host much of their physical UK-based computing capacity, operating cloud services for public and private customers across a large number of individual data centres and cluster 'availability zones.' In 2023, data centres accounted for 18% of West London's electricity demand putting incredible constraints on the local grid which have only grown since.

While in/direct impacts of the West London data cluster have not yet been properly documented, there are many risks to pay attention to here. Besides increasing carbon emissions from data centres' increasing use of on- and off-grid gas supplies, a recent review study of the potential environmental and housing implications of data centre expansion in West London foregrounds the growing risk of planning disputes, public discontent and loss of community resilience as data centres are granted expanded property contracts and redirect large portions of electricity grid capacity (Shivam 2025). Meanwhile, local inhabitants face housing delays and shortages, failing and fragile grid capacities and worsening energy inequality. The danger of UK electricity grid fragility in relation to data centre power consumption was confirmed in October 2026 as Microsoft broke its contracted role as the anchor tenant of the UK's largest AI data centre project in Loughton, Essex, because of concerns over delayed, insufficient and irregular power supply (Topham and Down 2026).

Pressures on local grids, and property and land use relations, are particularly felt in cloud cluster areas such as West London where “all data centre campuses … are now being planned with AI in mind” resulting in the significant expansion of “power densities” and “floor loadings” consumed by hyperscalers like Microsoft and AWS (CBRE UK 2026).

Other risks involve the exacerbation of ‘data heat islands’ and the reshaping of land use relations with resulting biodiversity loss. Large clusters of servers and cooling systems like in West London reject substantial amounts of waste heat, which, if uncaptured, can raise surrounding land and microclimate temperatures increasing stress on local residents as well as local urban vegetation and parks. A recent study even finds that the land surface temperature around a larger AI data centre can increase by 2 degrees Celsius with significant impacts on the welfare of both residents and ecological systems (Marinoni et al. 2026). Further, the planned buildout of AI-ready hyperscale facilities often on Metropolitan Green Belt land on the fringes of the UK’s major urban centres, like London but also beyond, pose detrimental risks of biodiversity decline from carbon emissions and land removal. In North Ockendon, north-east of Greater London, the hyperscale AI East Havering Data Centre is planned to usurp 218 hectares of greenbelt land (currently used for crops, wildlife and leisure), requiring 600 megawatts of continuous electrical input, roughly equivalent to the power demand of one million households (Stoddart 2026). Planning documents disclose that the centre’s annual emissions would be equivalent to 8,480 long-haul flights between London and New York. For an example further north of the UK, in 2026, North Lincolnshire council gave planning permission for the Elsham Tech Park, a 2 million square metre data centre campus housing 15 data centres, with estimated peak annual carbon emissions higher than all of the UK’s domestic flights (Bharadia 2026).

While contracted tenants have not been disclosed for these sites yet, all facilities are being prepared for hyperscale cloud and AI operators, like AWS and Microsoft, who also have long-standing relations with facility developers such as Equinix. Smaller size centres also harm biodiversity, such as the Google data centre threatening to destroy a 52 hectare Arena Raceway wildlife site in Essex, home to a unique grass- and woodland mosaic with hundreds of important plant and animal species such as Brown-banded Carder Bee and Dingy Skipper butterfly invertebrates, endangered Broad-leaved Cudweed plants and red listed Nightingale birds (Hetherington 2026). As noted by the UK Wildlife Trusts (2026), while the UK Government struggles to meet its goal of protecting 30% of England’s land and sea for nature by 2030, data centres keep eating away at large areas of rural and urban lands which could be used as nature-rich commons for communities and wildlife alike.

Spotlight: data centres versus resident wellbeing in Slough, Greater London

Public discontent from data clusters’ exacerbation of the unequal distribution of life-affirming services and resources is already becoming reality in the town of Slough. Major plans for cluster expansion include two Microsoft and Amazon data centres which would allow the region’s already expansive industrial data estate to encroach further upon residential areas. In

response, concerned Slough residents have started a protest campaign, joining protesting communities in Devon, Essex, Tower Hamlets (London) and Scotland, alongside wider global movements. One of the campaign's key demands is that data centre buildout is paused until proper investigations have been made into their cumulative social and environmental effects, given that no such study has been made despite the presence of hyperscale operations since the early 2010s.

The Slough Borough Council declared bankruptcy in 2021, and the town struggles with long-term poverty, high housing costs and health inequality. Instead of addressing these issues, local authorities continue to give concessions and favourable planning permits to data hyperscalers with few if any demonstrable benefits for local residents. Ambily Banerjee, a long-term resident and founder of Slough Against Data Centres, says that, "we have not seen a decline in our council tax. We have not seen our high street improve. We have not seen any improvement in the quality of life" (Gabert-Doyon and Steinberg 2026). Instead, data infrastructure buildout is impeding construction of new homes while directly reducing the town's biodiversity and residents' access to green spaces, worsening both housing and nature crises. For example, to compensate for its bankruptcy status, the council sold off a former factory to data centre developer Equinix in 2022, which was originally promised for 1000 new social and affordable homes. Of equal gravity, in 2026, Housing Minister Matthew Pennycook granted planning permission for a major data centre appropriating 20 acres of remaining greenbelt land in Slough, though the developing firm hopes to increase this to a 58-acre data cluster.

2. Ecological aftermaths: The fallout of digitalised warfare

The ecological beforemaths of military digitalisation in the UK brought us from the nickel mines of Indonesia, to data centres stretching from West London to Dublin to the US, through an intricate web of raw material processing, component manufacture and infrastructure buildout. In this section, I turn to the ecological impacts generated along the *downstream* of a digital military technology's lifecycle, that is, during or after deployment or disposal. I cover two 'end-of-life' geographies: the ecological fallout of military operations' increased reliance on autonomous weapons and AI-enabled targeting; and the human and environmental health consequences of waste military munition and electronic equipment disposal. Here we encounter a fourth political-geographic category of essence: that of war, its making and its aftermaths.

The ecological fallout of drone war and algorithmic targeting

Recent and ongoing military campaigns in Ukraine (2022-), Gaza, Palestine (2023-) and Iran (2026-) have made the growing digitalisation of military force and forces into lived realities on and off the 'battlefield.' Drawing on these active war geographies, we might infer a great deal about the human as well as ecological fallout of such force. Importantly, though these operations are primarily conducted by Russia, Ukraine, the US, Israel and Iran, the UK is in/directly implicated with the capabilities deployed therein. While separated into national procurement

systems, the development, export and use of advanced digital military systems hinge on a global network of arms, tech and data giants alongside countless tech startups, subcontractors, public and private capital streams, and state, corporate and academic research and development units (see Edwards 2026a; El-Shewy et al. 2025; Feinstein et al. 2026; Stavrianakis 2025). We therefore need to recognise that UK digital and military procurement practices have, in various non/traceable ways, contributed to the cloud-supported, AI-driven, autonomous military force deployed by Ukraine, the US and Israel, though to a lesser extent by Russia and Iran because of the siloing of the military-industrial complexes of NATO enemy nations.

The overall climate and ecological impacts of the military assaults on Ukraine, Palestine and Iran are myriad and vast (see e.g. CEOBS 2026; Neimark et al. 2026; Weizman 2024). For the purposes of this briefing, I focus here on the specific impacts that have arguably been compounded by the increasing use and sophistication of cloud-based, AI-enabled and autonomous military systems. Perversely, for arms, tech and military producers and practitioners, the war in Ukraine is considered a "real-time laboratory" and "accelerator" through which to scale global military innovation at pace, especially in relation to emerging technologies like semi- to fully autonomous drones alongside electronic, algorithmic and data-centric warfare systems (see e.g. Digital State UA 2025; DW News 2026). Besides guided 'precision' cruise and ballistic missiles alongside missile interceptor systems, a wide range of single-mission or 'suicide' drones and loitering munitions – many of which are cheaply built, smaller-scale "fibre optic drones" (Moreland 2025) – have been deployed in great numbers by both Russia and Ukraine.

All of these weapon systems leave behind large quantities of detritus and component hardware, littering entire fields, forests and cities with metallic splinters, intact guidance kits, lithium batteries, fibre-optic cables, unexploded ordnance, and highly corrosive rocket fuels, missile propellants and military-grade explosives. Together, these materials release toxins into the air, water and soil that pose great long-term risks to human and environmental health both at and beyond the sites of immediate impact. I exemplify these risks when discussing the contexts of Palestine and Iran below. Of particular concern in Ukraine at present, however, is the spread of fibre-optic cables: about 10% of Ukraine's drone production is estimated to consist of smaller systems that use fibre-optic cables to jam interference from electronic warfare, including a spool container which usually holds 5-20, though at times up to 41, kilometres of cable (Moreland 2025). These cables end up draped across entire frontline areas; rarely recovered, they are often damaged by explosions or fires and, even when degraded, could persist in the environment for more than 600 years. When damaged the cables risk releasing PFAS, microplastics and harmful gases like carbon monoxide and nitric oxide, all of which bioaccumulate with potentially harmful effects for human and non-human animals.

If Ukraine is considered a testing ground for autonomous weapons, Gaza and Iran have been turned into laboratories of AI-enabled targeting (and in Gaza, much more, see e.g. Mhajne 2025; Mukim et al. 2025; Rose and Çelik 2026). The sheer scale and pace of destruction in Gaza and Iran – of urban, industrial, agricultural and natural environments – has largely been enabled by targeting systems and software relying on data stored on cloud platforms and

collected, analysed and operationalised by artificial intelligence programmes (Hammad 2026). To operate these systems, the US and Israel rely on cloud services and infrastructure provided by commercial giants like AWS, Google, Microsoft, Palantir and OpenAI – the same providers on which hinges the UK MOD's Digital Backbone and AI-enabled weapon and C2 systems. For example, in February 2026, the US Department of War used Palantir's AI decision-support systems Maven Smart System, integrated with Anthropic's Claude AI, to hit 1000 targets in 24 hours as part of Operation Epic Fury. Maven is in turn hosted by AWS data centre servers. Many of the hit targets were civilian, exemplified by the bombing of a school in Minab killing 123 children, where a leaked Pentagon report confirmed Maven's targeting lists included outdated intelligence unverified by US military staff (Bartenstein and Karra 2026). By July 2026, US-coalition strikes on Iranian targets are estimated at more than 13 000, involving many more thousands of individual munitions.

In Gaza, Israel has relied in particular on three AI decision-support systems – Lavender, The Gospel, and Where's Daddy? – to list, score and locate targetable individuals. These systems are presumed to be partly or indirectly supported by platforms like Microsoft Azure, Google Gemini, AWS Cloud and OpenAI's Chat GPT-4 (for an illustrative map, see Hammad 2026). AI-enabled targeting drastically increased the scale and pace of Israeli bomb strikes on the Gaza Strip: within 48 hours of Hamas' attack on October 7, the Israeli air force had hit 1500 targets; during the first six days, Israeli pilots dropped more than 1000 guided and unguided MK-80 series bombs per day (PYM 2026; Webber 2024). By July 2026, estimates suggest that 223 000 tonnes of explosives have been dropped with more than 38 hospitals, 96 health care centres, 12 universities, 1 million buildings and housing units, and 80% of schools destroyed or damaged (Altawell 2026; Desai 2024). Less than 1.5% of Gaza's agricultural land remains cultivable (UN News 2025).

Natural, urban and infrastructural destruction from these military operations impacts human and environmental health through myriad forms of atmospheric, aquatic and terrestrial contamination. The bombing of houses, roads, hospitals, schools and so on, in densely-populated urban areas in both Gaza and Iran have generated millions of tonnes of construction rubble which, apart from unexploded ordnance and buried human remains, contain potentially lethal levels of asbestos, industrial and medical wastes (see e.g. Bennett 2025). The US' bombing of oil refineries in Tehran, Aghdesieh, Shahran, and Karaj furthermore caused industrial fires that lasted for days, spreading plumes of black smoke and 'apocalyptic' smog, followed by black rain. Together, the smoke, smog and rain contained soot, ash, sulphur oxides, nitrogen compounds, benzene, formaldehyde and other fine particulate matter all of which can aggravate pre-existing respiratory and cardiovascular diseases and increase the risk of stroke, cancers and neurological disorders from prolonged exposure (Gibson et al. 2026; Sénéquier 2026). Meanwhile, the destruction of Gaza's solid waste, sanitation, desalination and water systems has compounded into a severe pathogen crisis, where water- and vector-borne diseases thrive in contaminated water sources, and in sewage and rubbish accumulating along camps, roads and beaches (Al Jazeera 2025; UNEP 2024). The intensity of strikes in both Gaza and Iran and the types of targets struck are also generating spikes in carbon emissions, with five million tonnes of carbon dioxide equivalent ($MtCO_2e$) released only two weeks into the Iran

war (Neimark 2026), while the first 15 months of the Gaza genocide generated 33.2. $MtCO_2e$ (Neimark et al. 2026). Contributing factors include the release of carbon embedded in housing and building materials and the loss of carbon capturing ecosystems like farmlands, orchards and native vegetation, alongside emissions from the bombing of energy and fuel facilities; fuel use for aircraft and other weapon platforms; energy use for operating AI-enabled targeting systems; and post-war reconstruction.

Finally, and of great significance, weaponry detritus – such as the components, materials and substances mentioned in relation to Ukraine above – leave behind a range of toxic chemicals and heavy metals with long-term, difficult to trace, health impacts that leach into in air, water and soil before being ingested by people and wildlife. Here, we can infer potential risks posed by exposure to military detritus on affected populations in Iran and Palestine from previous operations using advanced 'precision' weaponry, where studies have for instance found increases in congenital disorders, miscarriages, birth defects and cancers in places experiencing heavy bombardment during the US-led invasion of Iraq (2003) and Israel's Operation Cast Lead in Gaza (2008-09; see Griffiths and Rubaii 2024, 5-10). In sum, the types of ecological harm compounded by the extensive use of drones and AI-driven systems in Ukraine, Palestine and Iran are severe and contribute to the need for regulating their development and use.

Toxic disposal: electronic waste and post-war cleanup

A detrimental and largely invisibilised consequence of digitalisation – military and commercial – is electronic waste or so-called e-waste. Every year more than 50 million tonnes of e-waste is produced globally, projected to reach 82m tonnes by 2030 (UNITAR 2024). Worryingly, about 82.6% of all e-waste globally is *not* properly documented, collected or recycled, and the generation of e-waste is rising five times faster than its documented recycling (UNITAR 2024; WHO 2024). These waste streams are exacerbated by the rapid scaling of generative AI and the increased demand for component hardware, like semiconductors, across military and commercial sectors. A study from 2024 anticipates that generative AI alone could add up to 5m tonnes, while data centre expansion could add up to 4.2m tonnes, of e-waste by 2030 (Wang et al. 2024, cited in Barrett-Taylor et al. 2026, 40). Amid plans to digitalise both military and civil sectors, the UK is already the world's second largest per capita producer of e-waste, with a study from 2016 estimating the UK's yearly average at 6m tonnes per year – of which only 31.2% is recycled (Forti et al. 2018).

E-waste consists of highly toxic electronic scraps, the management of which maps onto global geographies of toxicity, labour exploitation and structural marginalisation. Most waste is produced by the US and Europe (notably the UK) and then exported to scrapyards in Africa and Asia (particularly Ghana, Nigeria, China and Thailand) where it feeds into calamitous human and environmental health conditions and generates toxified sacrifice zones akin to those of mining (Sovacool 2019). E-waste can contain over 1000 hazardous materials, including plastics, chemicals and heavy metals such as dioxins, furans, beryllium, cadmium, mercury, lead, arsenics, asbestos, radioactive substances and PFAS-based flame retardants. Studies show that e-waste accounts for 70% of the toxic heavy metals found in landfills even when it only

forms 2-5% of its solid volume (Ankit et al. 2021). When buried in landfills, such toxins leach into local soils, rivers and groundwater.

This is felt particularly acutely in Agbogbloshie, near Accra in Ghana, home to one of the world's largest e-waste scrapyards where precarious labourers mine valuable materials from end-of-life electronics amid conditions marked by disease, poverty, gender inequality, child labour, and ethnic and religious marginalisation (Sovacool et al. 2020, 2; see also Little 2021; Sovacool 2019). Here, non-valuable materials are separated by open-air burning or mercury and nitric acid baths causing scrapyard workers and nearby communities to inhale or ingest elevated amounts of toxic chemicals associated with cancers and the corrosion of bodily functions, such as the liver, skin, kidneys, reproductive and neurodevelopmental systems. A large though undisclosed quantity of the UK's yearly e-waste ends up in West Africa, including Agbogbloshie (see Rowe 2011; Sovacool et al. 2021, 4).

Military technologies, especially those with advanced digital functions, exacerbate these waste streams, including decommissioned components from sensors, displays, guidance kits, ships, aircraft, electric vehicles, radar, batteries, hard drives, computers, servers, drones, artillery and propulsion systems; most of which are central to AI-enabled autonomous weapons or C2 systems. Military-grade electronics are also particularly sought after as they often contain higher concentrations of 'precious' metals to withstand extreme environments for long periods of time, such as gold, silver, platinum and palladium – all with hazardous afterlives when burnt or melted. Advanced fighter jets like the Eurofighter Typhoon, F-16 or F-35 are estimated to generate between 1-2 metric tonnes of e-waste per aircraft, meanwhile the guided Javelin anti-tank or Tomahawk cruise missile systems could account for 100-300 kilogrammes per system (E-Waste Recyclers 2024). These numbers are only suggestive given the lack of (publicly) available data on the resource lifespan of the military technologies procured by the UK and other NATO members. Nonetheless, they serve as concerning indications of the extent of e-waste generated by heavily digitalised military technologies.

Paradoxically, the US Department of Defence has found that e-waste exported to scrapyards such as in West Africa and China is often repurposed into counterfeit microchips – particularly integrated circuits – which are then unknowingly purchased by US military contractors and consequently integrated with the US military's missile guidance, satellite antenna and night vision systems. These potentially faulty chips pose great risks to the functionality of military systems, "given that integrated circuits serve as the brains for so much of the military's technology" (Greenemeier 2017). Despite the above harms to human and environmental health, the harmful afterlives of ever-'smarter' technologies is seldom mentioned in relation to the rapid digitalisation of military equipment, and neither of the UK MOD strategies on defence-related digital, AI and cloud services engage with the issue of end-of-life management of such services' physical hardware.

In addition to the deadly conditions of scrapyards, toxification from improper disposal or recycling of military e-waste is felt similarly acutely in contexts of post-war 'clean-up.' Rubaii and Griffiths (2025, 4) show how the processing of debris, such as from weapons or destroyed buildings and infrastructure, *defers* and *disperses* the harmful effects of military violence, suggesting that "clean-up is never an aftermath but rather a reformulation of military violence,

the continuation of war by other means." People engaged in practices of collecting, cleaning, recycling or disposing of post-war debris in places such as Iraq are exposed to bodily deterioration and chronic disease as metal residues like lead, cobalt, cadmium and copper toxify the air, water and soil in which they operate (see also Griffiths 2022, 284-85). To linger on the example of Iraq, people undertake such cleaning on different scales and in different personal or professional capacities, such as an Iraqi couple cleaning missile casings and rubble from their bombed-out home; an Indian migrant scrap-metal worker refashioning weapon components into construction materials; or a former US soldier working in proximity to an open-air burn pit at a US airbase, burning thousands of tonnes of military waste (Rubaii and Griffiths 2025). For all of these people the embodied effects of post-war cleanup were lifelong and extended to their children through congenital poisoning, including "premature babies, 'disfigured and born dead'" (Rubaii and Griffiths 2025, 6).

With the advancement of war's digitalisation, we might infer that the scale of military electronic wastes to be recycled or disposed of in the wake of military operations will increase accordingly; for instance captured by the sheer amount of component detritus generated by the use of drones in Ukraine; or the intensity of strikes – fighters deployed, munitions dropped, buildings and hazardous infrastructure destroyed – generated with AI-enabled targeting systems in Gaza and Iran. Like with the effects of mining, component manufacturing, computing infrastructure and e-waste processing as outlined in this briefing, the bodies and territories bearing the brunt of post-war cleanup are often far removed from those who develop and deploy the advanced digital technologies on which military operations rely, such as the UK Government and the many mil-tech sub/contractors constitutive of British military force.

3. Spotlight: Biodiversity loss across four geographies of military digitalisation

I now turn to the specific issue of military digitalisation's impacts on biodiversity. While the previous sections have already hinted at the loss of natural areas with associated plant- and wildlife from digital war's ecological before- and aftermaths, this section elaborates on such loss in greater detail. Here, I trace the loss of or threat to biodiversity – species, habitats, ecosystems – from military digitalisation before, during and after deployment by thinking through the combined impacts across all four political-geographic categories outlined in the briefing: extraction; manufacturing; computation; and war. As I note below, these geographies generate very similar threats to biodiversity.

Firstly, geographies affected by mineral extraction and processing are especially disastrous for biodiversity. From the direct clearing of different terrestrial and aquatic topographies – deserts, mountains, rainforests, rivers, ocean coastlines – to the large-scale generation of often permanent deposits of toxified solid and liquid wastes, mineral and metal extraction constitutes one of today's worst threats to plant and animal species protection. Recent studies find that global mineral mining activities are responsible for a biodiversity decline (measured in mean species abundance) equivalent to the transformation of 6 million hectares of pristine habitat into degraded landscapes devoid of all original species (Yu et al. 2026), with nearly 8% (4642) of global vertebrates threatened especially by quarrying (Lamb et al. 2024).

Such mining-related species decline is twice as high as anticipated, with decline hotspots found in Indonesia, New Caledonia, Suriname, Brazil and Peru. Strikingly, 77% of mining-driven biodiversity loss occurs outside of the countries, such as the UK, accounting for the greatest demand for and consumption of end products. Nickel, copper and precious metals constitute three of the five elemental groups driving 82% of total biodiversity loss from global mining.

Returning to the example of nickel extraction, because of their occurrence in tropical conditions, the red topsoil laterite ores from which much of today's nickel boom is sourced are located in biodiversity – and carbon capture – hotspots often with rich, hitherto intact rainforests. See *Case study box I* (section 1, pages 11-13) on the large-scale loss of rainforests in Indonesia. The same is true for the open-pit nickel mine in Córdoba, Colombia, where the Australian mining giant BHP Billiton has gouged red laterite from the ancestral lands of Afro-Colombian and indigenous Zenú communities for almost half a century: causing the near-total collapse of traditional fishing from polluted river basin habitats; and clearing dense tropical forests previously rich with spider monkeys, jaguars and tapirs (Mariani et al. 2023). To offset this loss of native biodiversity, Billiton has invested in equally disastrous large-scale palm oil and non-native teak monoculture plantations which are inhospitable to local wildlife, while drying out local water sources. Likewise, in Palawan, the Philippines, multinational mining companies haul hundreds of thousands of tonnes of nickel laterite from open mines steadily displacing some of the Philippine's largest remaining areas of old-growth forest, mangroves and coral reefs (McClure 2026).

Finally, a similar assault on old-growth rainforests is happening across the Congo Basin, home to the world's second largest rainforest which constitutes an essential sink for global carbon emissions, similar to the Amazon. Here, industrial-scale as well as artisanal copper, cobalt and coltan mining projects have cleared an unknown though vast quantity of once thriving forest, threatening both forest communities and species like lowland gorillas. Estimates suggest that at least 8.6% of the DRC's entire tree cover, also beyond the Basin, has been cleared by mining operations (Constantine and Wolff 2023). Along the DRC's copper-belt, high concentrations of cobalt – a radioactive element – have also been linked with the vanishing of fish from local streams and the death of crops and worms, steadily eroding soil fertility.

Secondly, manufacturing and computing geographies have similar effects on biodiversity decline as those of extraction: large-scale hardware factories (such as for semiconductor equipment, chemicals, and front- and back-end chip foundries) and regular to hyperscale data centre infrastructure all require the direct removal and fragmentation of habitats and ecosystems, while their operation reduce local water sources and generate waste flows with indirect harm on habitat quality. These indirect harms, such as from exposure to heavy metals, are similar to those noted in relation both to mining (above) and warfare (below). A particular threat posed by semiconductor supply chains, in particular, is the potential leakage of forever chemical compounds, such as potentially carcinogenic PFAS, during their manufacture and transport or as part of waste slurries and waters at front-end fab sites. Resisting degradation for thousands of years, PFAS bioaccumulate in soil, groundwater, animals, plants and the human body, slowly altering genetic makeups, blocking soil respiration, damaging organs and immune and reproductive systems, and increasing the risks of cancers and other illnesses (Horel 2023).

For concrete examples of biodiversity threats from data centre expansion in the UK, see *Case study box II* (pages 18-20).

Fourth and finally, the conduct of war asserts similar though exacerbated pressures on biodiversity. It is important to note that war geographies include sites where digital war is both prepared for (such as the Uncrewed Systems Centre in Swindon, the Salisbury Plain Training Area or QinetiQ's DroneWorks hub at MOD Boscombe Down where the UK's digital military forces are trained and tested); and conducted (where military operations happen, with ensuing aftermaths). For this briefing, however, I focus on the latter. If we linger on the examples of Ukraine, Palestine and Iran as wars marked by autonomous technologies and artificial intelligence – with which the British military-industrial complex is closely bound up – these are contexts where species, habitats and ecosystems are under great threat. The loss of forests, farmlands and native vegetation from bombing, or from wildfires sparked by artillery fire, is particularly damaging to flora and fauna. Estimates suggest that more than 80% of Gaza's tree cover has been completely lost or severely damaged (UNEP 2025). The war in Ukraine has similarly damaged around three million hectares of forests, reducing Ukraine's yearly carbon capture capacity by 1.7 million tonnes (Yermolenko 2025). Ukraine is home to more than a third of Europe's biodiversity, and hundreds of animal, plant and fungal species are now threatened by the warfighting. The spread of fibre-optic cables furthermore pose the serious – and documented – risk of life-threatening entanglement for birds, bats and ground dwelling mammals (Moreland 2025). When wildlife are not wrapped up in the cables, the cables can still act as barriers to movement between habitats across the sky, waterways and ground.

Relatedly, as detailed in section 3, the use of explosive weapons and bombing of buildings and hazardous infrastructure generate toxic chemical, plastic and heavy metal residues which fume into the air, leak into the soil and leach with rainwater into nearby waterways. Besides harming the health of humans, these toxins stunt the growth of plants and vegetation; poison birds and wildlife through ingestion; and degrade habitats, such as when species are driven from forests and grassland canopies because of poor and acid air, or when aquatic life stop reproducing as their organs fail from methylmercury poisoning (Babanina et al. 2025; Lawrence et al. 2015). The toxins also bioaccumulate in plants and organisms which are then absorbed by predators when eaten, leading to the contamination of entire food chains. Notably, these forms of pollution are often the same as those generated at sites where minerals and metals are mined; and where military and other e-wastes are disposed of, such as at end-of-life electronic scrapyards like in Ghana or as part of post-war environmental remediation efforts. With the expansion of both the scale of destruction during war and the scale of electronic waste generated by the digitalisation of UK and other military equipment and operations, these threats to biodiversity are due to expand as well.

In sum, then, military digitalisation undermines biodiversity through its development, deployment and disposal. Crucial here is to recognise the biodiversity impacts across extraction, manufacturing, computation and war geographies as not only similar but directly linked. Taken together, localised threats to species and habitats compound across the lifecycles of digital (and) military technologies to produce a complete threat picture detrimental to the resilience of

local communities and ecosystems in the face of climate breakdown, as well as to efforts to stem species loss, ecological degradation and rising temperatures on a global scale.

Conclusion

Military digitalisation is often discussed primarily through questions of strategic autonomy, security governance or the laws and ethics of war. However, as demonstrated by this briefing, the advancement of digital systems and services for military operations hinge on extensive networks of digital hardware and infrastructure – marked by opacity and poorly understood lifecycles – that reshape landscapes, consume life-affirming resources and spawn toxic wastes. In this sense, the digitalisation of armed forces pertaining to a sole nation like the UK depends upon linked yet globally dispersed geographies made hazardous to human and environmental health by raw material extraction, component manufacturing, computing infrastructure, and the development, deployment and disposal of digital-age weaponry. Common across these four geographies of extraction, manufacturing, computation and war are patterns of resource capture, ecosystem destruction, habitat degradation, poisoning of animals and plants, and public health deterioration.

An important finding here is that when recognising digitalised military systems' embeddedness in material conditions that both precede and succeed the use of a military cloud storage software, 'precision' loitering munition or targeting algorithm, we learn that the impacts of digital war's ecological before- and aftermaths are felt far from the sites of final development or deployment. By drawing together the before- and aftermaths, we draw attention to how military digitalisation in general, and autonomous weapon systems in particular, are implicated in a global continuum of bodily and ecological degradation, whereby certain lives and lived environments are made insecure so as to secure the digitalisation of the British military and its lethal capabilities. As outlined in this briefing, such lives and lived environments include workers and communities bound to nickel and copper extraction in Indonesia and the DRC, marked by exploitation and toxification; front-end chip fab workers in Taiwan, dealing daily with tonnes of forever chemicals; local residents whose water, electricity, greeneries and built environments are increasingly consumed by data centre clusters across the US, UK and Ireland; survivors of Maven or Lavendar-guided strikes in Iran and Gaza, faced with the often carcinogenic task of cleaning up war's toxic remnants; or chronically ill e-waste scrapyard workers in Ghana.

And yet, a crucial issue with the task of mapping the lifecycle impacts of military digitalisation is the lack of transparency and traceability that shape mineral, digital (information and communication technology) and military supply chains, down-, mid- and upstream. This lack is owed both to the increasing complexity and diffusion of raw material, manufacturing and waste value chains; and to the strategic obstruction of traceability and the "anti-transparency" practised by the state, corporate and military gatekeepers of said chains (see Griffiths and Rubaii 2025, 10; Hess 2024; Willemsen 2025). The task is further complicated by the 'dual use' status of most digital technologies, hardware and infrastructure, alongside their associated material input and output streams. As noted, I have been unable to access public information with which to *directly* link, for example, any one data centre with any one UK MOD cloud-storage function or autonomous weapon system; meanwhile much of the e-waste

generated by the UK MOD ends up in the same waste streams as households and commercial industries. Gaps in knowledge therefore constitute a critical threat as much to prospects of ecological remediation amid the militarisation of digital development, as to efforts to regulate the growth and uptake of emerging technologies like AI for military purposes. These gaps are notable and warrant researchers', scientists' and affected communities' continued labour to expand existing evidence, such as by targeting individual hardware value chains, documenting their resource capture and pollution patterns, and mapping their raw material, infrastructural and corporate entanglements.

Further research should include: comprehensive estimations of the carbon emissions of the integration of cloud and AI functions with military organisations and operations, including the carbon costs of production, deployment and post-war reconstruction; multidisciplinary long-term studies of the types, spread and effects of chemical and heavy metal toxification of digital weaponry lifespans on human and environmental health; the amount of e-waste generated by the digitalisation of individual militaries, such as the UK's, and the trajectories of recycling or toxic disposal along which this waste travels; long-term effects on particular species and ecosystems across geographies of extraction, manufacturing, computation, and war making and preparation, in and beyond the UK. Crucial to all such inquiries is an unwavering emphasis on how military digitalisation contributes to three political-economic/ecological conditions built into today's convergence of social, economic, ecological and military crises: first, the concentration of power and capital with state, corporate (tech) and military elites; second, the uneven distribution of benefits, burdens, harms and responsibilities; third, and relatedly, the enduring – imperially rooted – differentiation of what bodies and territories are to be sacrificed and which are to be secured for the advancement of both military and digital capabilities.

Finally, the lack of accessible data constitutes a crucial finding on its own: state, corporate and military obstruction of public as well as academic scrutiny of the material lifecycles of British military equipment and operations should alert us to the probability of their large-scale damage. Here, I borrow from Górska and Griffiths (2026, 15), in stating that, the evidence presented in this briefing of the ecological impacts of digitalisation – inclusive and exclusive of direct military applications – "should be understood as indicative rather than exhaustive, as a sign of something worth obfuscating or classifying." Faced with the rapid scaling of military digitalisation and the acceleration of associated toxic waste streams and energy, water, land, mineral and other demands, it is crucial that we draw on existing evidence to indicate the types and degrees of harm thereby anticipated, so as to regulate and, at best, prohibit the unhinged digitalisation of weapons, war and warfighters before these harms become unavoidable or irreversible.

Figures and tables

Table 1

Minerals	Component hardware	Infrastructure networks	Military systems	Ecological impacts	Affected geographies
Copper	Semiconductors (e.g. silicon and compound [gallium and germanium] wafers)	Satellite networks (communication, sensing and navigation systems)	Cloud- and AI-enabled on and off-base command-and-control systems	Surface and underground mining e.g. causing pit-wall landslides and cave-ins, and releasing toxic airborne dust and gases.	Chile, Peru, Argentina, Bolivia, Brazil
Lithium	Microchips (e.g. memory chips, graphics processing units [GPUs], AI accelerators)	Telecommunications networks (fibre-optic and undersea cables)	Semi- or fully autonomous vehicles (air, land, sea, underwater)	Acid mine drainage and other pollution of lakes, rivers, streams and groundwater from spread or dumping of toxic tailings	US, Canada, Cuba
Cobalt	Sensors (e.g. cameras, infrared and electro-optical systems, radar, LiDAR)	Cloud services and platforms	Portable soldier systems (cloud, AI, electronic warfare, advanced sensors etc.)	Leach and spread of toxic mine tailings (including chemicals and heavy metals, e.g. mercury and cyanide)	DRC, Mozambique, Madagascar, Tanzania, Ghana, Nigeria, Rwanda, Guinea
Nickel	Batteries	Computing facilities (data centre clusters, cloud- or edge-computing facilities, quantum and supercomputers)	'Precision'-guided munitions (e.g. laser, GPS or inertial navigation system-guided bombs, missiles and mortars)	Deforestation	Australia
Graphite	Communications hardware (e.g. radios, satellite terminals, antennas)	Data processing infrastructure (e.g. server farms and storage arrays)	Digitally advanced artillery or munition launching systems (howitzers; rocket, mortar and missile launchers)	Soil and top-soil erosion	Indonesia, Myanmar, Philippines
Rare earth elements[4]	Rare earth magnets	Data centres	Military air platforms with onboard cloud, AI and autonomous functions (fighters, bombers, helicopters, logistics craft)	Red-mud waste from bauxite mining (e.g. threats from alkaline airborne dust or breached storage ponds)	China, Taiwan, South Korea, Japan
Gallium and germanium	Physical servers (e.g. rack, blade, GPU, AI or	Electricity grids	Military land platforms with onboard cloud, AI	Air pollution from smelting, mining dust and blasting	Kazakhstan, Russia

[4] Consisting of 17 elements, including neodymium, terbium, dysprosium and samarium for instance used for permanent magnets in drones, electric motors, sensors and guidance systems (IRE 2026; Klinger 2018).

	edge-computing servers)		and autonomous functions (battle tanks, armoured combat vehicles, logistics trucks)		
Silicon	Data-storage devices (e.g. hard disk drives [HDDs] and solid-state drives [SSDs])		Military sea platforms with onboard cloud, AI and autonomous functions (aircraft carriers, destroyers, frigates; attack, ballistic missile and nuclear submarines)	Radioactive wastes	Portugal, Spain, Sweden, Bulgaria, Poland, Germany, Armenia
Gold	Portable computing devices		Electronic and cyberwarfare systems (e.g. radar-jamming or electronic attack systems)	Avian, terrestrial and marine habitat destruction	
Aluminium				Energy- and waste-intensive purification, processing, refining and smelting	
Tin				Occupational health harms and poor labour conditions	
Tantalum				Social and economic stressors (such as corporate exploitation, and armed and gender-based and sexual violence)	

Table 1: list of examples of military AI-enabled autonomous and C2 systems and their related minerals, components, infrastructure, ecological impacts and affected geographies.[5]

[5] This is an indicative rather than exhaustive list and all categories are listed separate from (with no direct horizontal relationship to) each other. For details on data centres and cloud services, see Bresnihan and Brodie (2025); de Vries-Gao (2025); Monserrate (2022); on minerals, see Anderson (2024); Andreucci et al. (2023); Griffiths and Rubaii (2025); Rubaii et al. (2025); Selwyn (2020); on military systems and AI, see Barrett-Taylor et al. (2026); Blanchard et al. (2026); Burilkov et al. (2025); on chips and semiconductors, see Hess (2024); Suleimenova (2025).

Figure 1

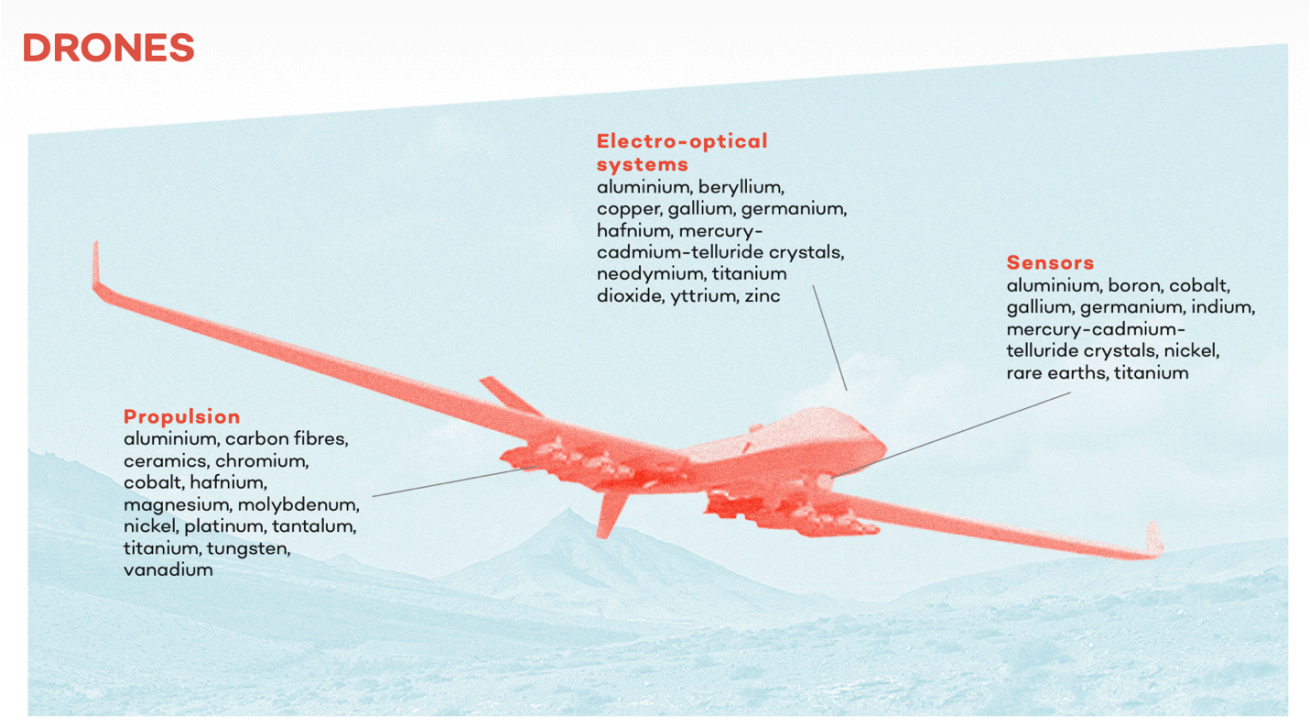


Figure 1: Infographic of minerals commonly used for larger drones operated by the UK RAF, such as the MQ-9 Reaper. Source: Daniel Selwyn, Martial Mining report, December 2020.

Figure 2

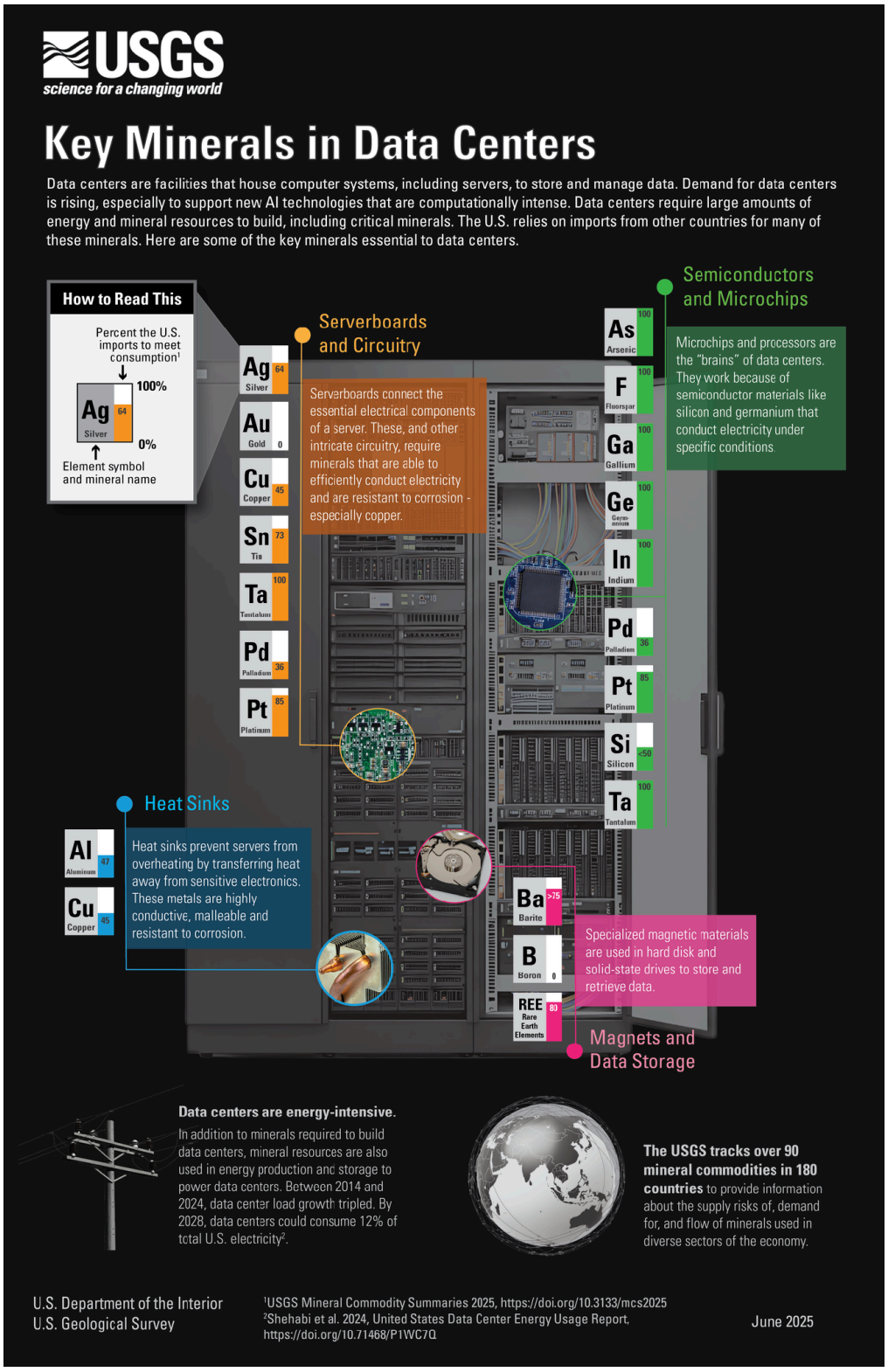


Figure 2: List of key minerals in data centres. Source: US Department of the Interior and US Geological Survey, June 2025.

Figure 3

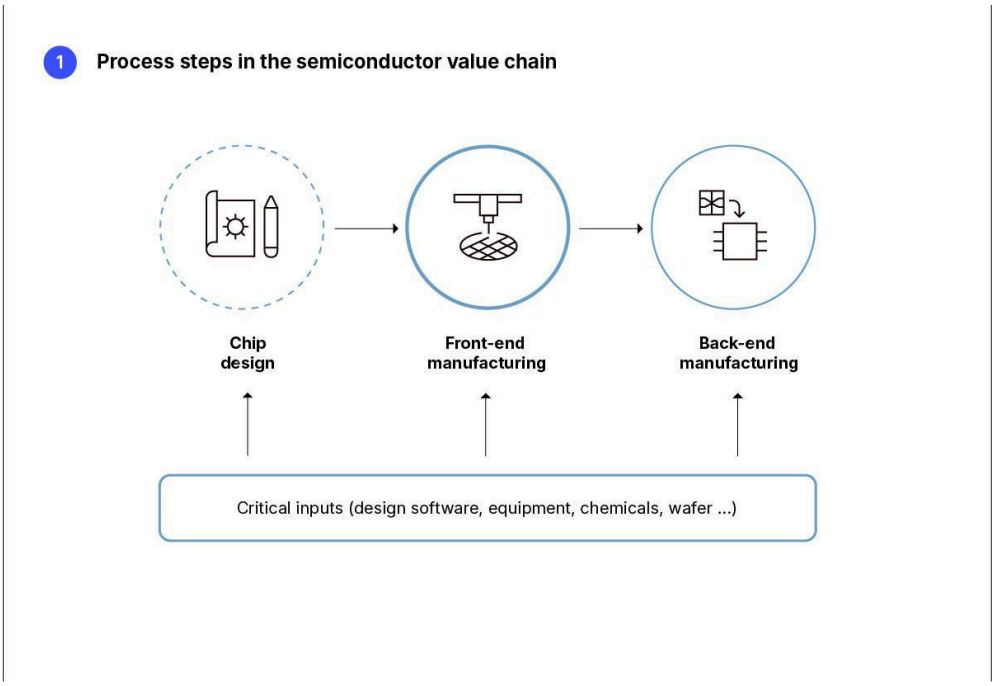


Figure 3: three steps of semiconductor device manufacturing. Source: Julia Christina Hess, Interface, June 2024.

Figure 4

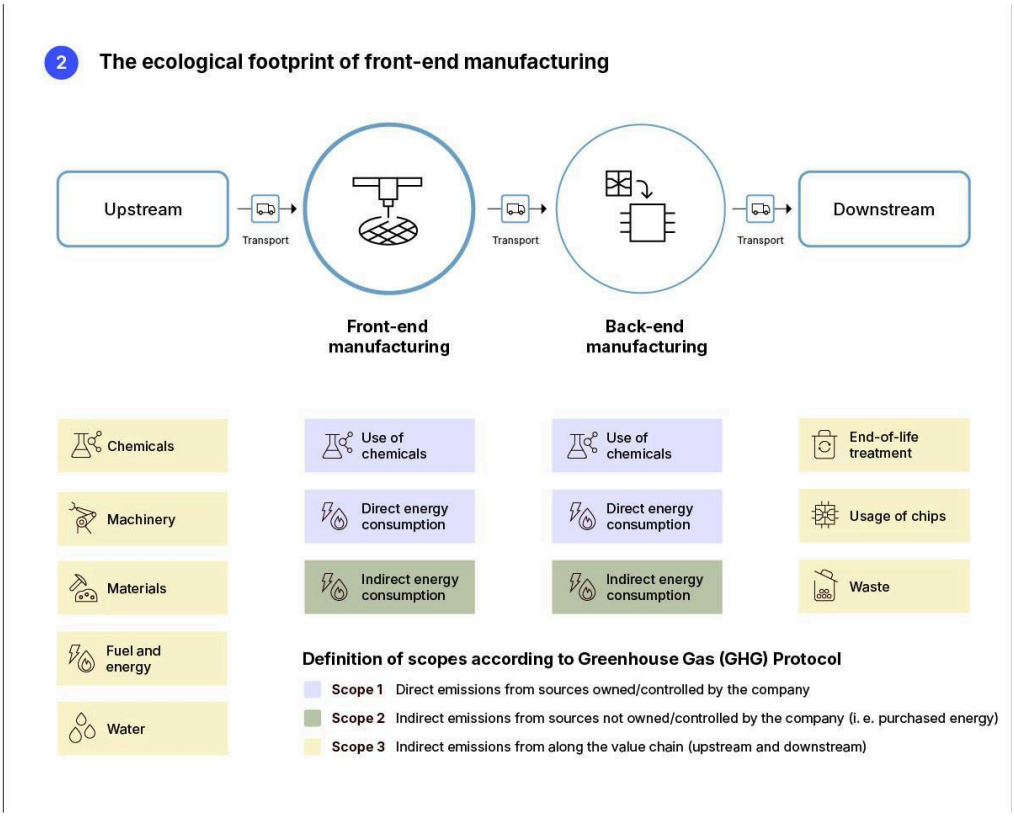


Figure 4: ecological footprint of front-end semiconductor device manufacturing. Source:

Julia Christina Hess, Interface, June 2024.

Figure 5

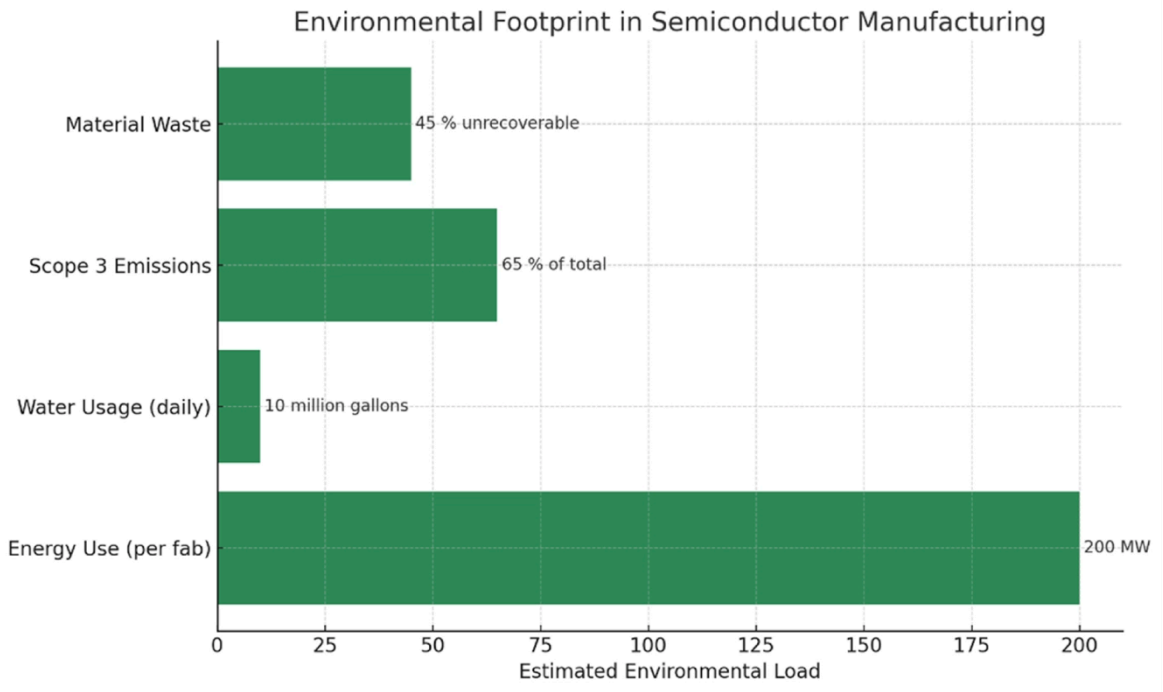


Figure 5: Semiconductor manufacturing environmental footprint chart. Source: Skyline Orbit Semiconductors, July 2025.

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