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**EUROPEAN SKY SHIELD INITIATIVE:
EVOLUTION AND CHALLENGES IN MULTI-
LAYER AIR-DEFENCE AGAINST DRONE
SATURATION AND HYPERSONIC MISSILES**

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Introduction

Scope and Strategic Question

European airspace is now the first line of defence against drone swarms, cruise missiles, ballistic missiles and new hypersonic threats. Saturation attacks with drones and follow-on salvos of missiles can overwhelm even advanced air defence systems, as seen in the drone-and-missile playbook used in recent Middle East exchanges and Ukraine (Liu, 2025, para. 27). Interceptor missiles often cost hundreds of thousands of dollars, while many drones cost tens of thousands, which shifts the cost calculus against the defender during protracted campaigns (Liu, 2025, para. 22). Russia has expanded production of cruise and ballistic missiles and fielded systems described as high-hypersonic and multiple independently targetable reentry vehicle (MIRV). The Oreshnik intermediate range ballistic missile (IRBM) framed as difficult to intercept even with upper-tier interceptors such as Arrow 3 or SM-3/SM-6 class systems (Hoffmann, 2024, para. 13; Powell, 2024, para. 6). The result is a persistent threat to European hubs within minutes of launch.

The European Sky Shield Initiative (ESSI), announced by Germany in 2022, brings together a growing group of European states to pursue a multi-layered air and missile defence through joint procurement and integration with NATO's Integrated Air and Missile Defence (IAMD) (Wachs, 2023, p. 4). Participation has widened to include EU and non-EU members, yet France and Italy remain outside the initiative while continuing to develop their medium-range ground-to-air missile defence system SAMP/T MAMBA and pressing for a stronger European pillar in air defence (Arnold & Fayet, 2024, p. 16). At the same time, ESSI members are contracting IRIS-T SLM/HF, Patriot PAC-3 MSE, and Arrow 3 as layered interceptors, with new orders adding cost pressure and raising questions about industrial balance inside Europe (Barrie & Giegerich, 2023, para. 6).

This paper asks how ESSI can adapt to drone saturation attacks and addresses the issue of intercepting hypersonic and manoeuvring ballistic threats, advance EU strategic autonomy, and how to keep full interoperability with NATO IAMD. The core argument is that a shield that links space-based missile early warning (SBMEW), a common battle management/command and control (BM/C2) layer, and national interceptors will cut decision time and raise European deterrence. Programmes such as ODIN'S EYE II (SBMEW) and TWISTER, the OCCAR-managed HYDIS/HYDEF hypersonic interceptor efforts, and the adoption of open standards for sensor-to-shooter networks can move ESSI from a procurement club to an integrated air defence architecture.

The gaps are clear: stockpiles of interceptors are limited, command arrangements across

borders are not yet harmonised, and costs are high (Burilkov & Wolff, 2025, p. 4). Europe can fund part of this through EU-level borrowing to accelerate production, bundle procurement, and reduce unit costs while improving interoperability (Wolff, 2024, para. 4). The aim of this paper is to map the threat picture, outline ESSI's current capability set and gaps, describe BM/C2 and interoperability needs, and propose concrete actions that keep NATO links and raise EU industrial resilience.

1. Threat Picture

Drone proliferation has been experienced both in state arsenals and violent non-state actors (VNSA), representing a complex threat to address for counter-unmanned aerial systems (C-UAS) (Dulligan et al., 2025, p. 1). Mass launches of low-cost expendable drones saturate radar and interceptor capacity, and then open corridors for more damaging cruise and ballistic missiles. That sequence using drones to saturate and missiles to strike, has been documented as a trend that can overwhelm even strong multi-layered shields and force defenders to ration interceptors (Liu, 2025, para. 10). A risk-based approach emerges in practice: prioritise critical infrastructure and accept that not every aerial threat can be intercepted during peak volume attacks (Liu, 2025, para. 30).

Russia's long-range precision-strike capability combines air, sea, and ground-launched cruise and ballistic missiles able to threaten targets throughout Europe. That mix supports a three-phase concept: counterforce on air bases and command centres, countervalue against critical infrastructure, and nuclear escalation if conventional means fail, which stresses ground-based air defence depth and resilience (Wachs, 2023, p. 2). Russian production has ramped up since 2022, with national mobilisation and industrial retooling, and assessments warn that European ground-based air defence capacity remains short of requirements to protect the eastern flank (Loorents, 2024, p. 2). NATO officials and allied capitals still identify air defence shortfalls and a need to raise readiness under new regional plans and the NATO Force Model (Loorents, 2024, p. 3).

New hypersonic and manoeuvring ballistic threats tighten timelines for detection, tracking, and engagement. The hypersonic threat label covers re-entry vehicles, quasi-ballistic manoeuvring missiles, hypersonic glide vehicles (HGV) and hypersonic cruise missiles (HCM) (Richardson, 2024). The shared operational challenge is high speed, manoeuvrability, and compressed decision cycles that demand space-based detection, fast discrimination, and multi-physics intercept windows (Richardson, 2024).

The preeminent threat to Europe is represented by Russia's hypersonic arsenal. Russia fields the Kinzhal (Kh-47M2) as an air-launched hypersonic missile from MiG-31K and Su-34, with

speeds above Mach 5, with an estimated reach of up to about 2,000 km, and conventional or nuclear warheads for ground and naval targets (Youvan, 2024, p. 6). RS-28 Sarmat (Satan 2) is a MIRV Intercontinental Ballistic Missile (ICBM) with global range whose payload versatility and advanced decoys are meant to keep a survivable nuclear retaliatory option (Youvan, 2024, p. 5). Tsirkon (3M22) is a sea-launched hypersonic missile using scramjet propulsion, reported up to Mach 9 for anti-ship strikes and power projection from Arctic and other naval axes (Youvan, 2024, p. 13). The Avangard is a hypersonic glide vehicle launched from an ICBM, with claimed speeds up to Mach 27 and flight manoeuvres intended to evade missile defences (Bernstein & Menke, 2019, para. 3). Avangard's primary purpose is to increase the survivability of the Russian strategic deterrent and keep a secure second-strike capability (CSIS, 2020, para. 4). In November 2024, the conflict in Ukraine saw the use of a new Russian hypersonic capability. Russia's Oreshnik Intermediate-Range Ballistic Missile (IRBM) is described as fast, difficult to intercept with Ukraine's current defences, and designed to stress upper-tier Ballistic Missile Defence (BMD) layers because of its high-apogee trajectories (Hoffmann, 2024, para. 13).

A missile-heavy campaign would also deplete European stockpiles of interceptors quicker than they can be replenished without a broader production surge (Burilkov & Wolff, 2025, p. 4). Europe also faces a volume problem as Russia expands output of cruise missiles and long-range loitering munitions, while many European armies need more medium and heavy units at high readiness and larger munitions stocks (Burilkov & Wolff, 2025, p. 2). That reality matches a wider lesson from Ukraine: air defence is a battle of resource management, where cheap drones and massed missiles can force the defender to expend limited, expensive interceptors (Liu, 2025, para. 29). ESSI must adapt to this saturation challenge with layered sensors, SBMEW, cross-border fire control, and a wider set of effectors, including high-energy lasers for counter-UAS, guns with programmable airburst, and cheaper interceptors for low-end targets (European Commission, 2022, p. 1; Dean, 2024, para.19).

2. Current Initiative and Capability Gaps

The European Sky Shield Initiative was created through a German-led effort in 2022 and counts 24 members, including non-EU and non-NATO participants (Withington, 2025, para. 3). The initiative runs four tiers of missile defence: short, medium, long-range and very long-range, with Skyranger 30 and IRIS-T SLM made in Germany by Rheinmetall and Diehl Defence, Patriot produced by Raytheon in the United States with Patriot missiles to be built in Europe through the COMLOG joint venture, and Arrow 3 as the exo-atmospheric option from Israel in cooperation with the United States, with the weapons to be integrated into a preexisting NATO mission (Desmarais, 2024, para. 22). ESSI emphasises a multi-layered

approach based primarily on ground-based air defence and fast acquisition of off-the-shelf systems tied into NATO IAMD (Wachs, 2023, p. 4).

The role of Skyranger 30 is to address the drone saturation challenge through counter-UAS point defence. Gun-based systems like the Skyranger 30 are cheaper than missiles against lower-end drones and help preserve interceptor stocks (Newdick, 2025, para. 17).

At the top layer, Arrow 3 provides an exo-atmospheric engagement option described as the highest layer within ESSI's initial concept, though industrial politics around non-European systems generate debate over strategic autonomy. France and Italy, who did not join the initiative, promote the SAMP/T MAMBA line and the next-generation Aster family for long-range and anti-ballistic roles, which sit alongside a broader push for EU industrial primacy in future interceptors (Arnold & Fayet, 2024, p. 16). That divide reflects different pathways toward autonomy: one prioritises speed through off-the-shelf procurements, while another prioritises a European supply chain for long-term resilience (Senel, 2024, para. 7).

The cost picture is stark. Bundled procurement can lower unit costs, but large volumes of PAC-3 MSE, and IRIS-T interceptors still imply major fiscal effort. Analysis of European requirements without the US estimates a need for €250 billion in extra annual defence spending in the short term, with bundling and EU-level debt as tools to finance air defence and other critical capabilities (Wolff, 2024, para. 4; Burilkov & Wolff, 2025, p. 5). NATO capability targets also point to a 400 per cent increase in air and missile defence capacity across Europe, reinforcing the depth of the gap (Olsson, 2025, para. 6).

In this setting, a strong top-down sensor layer is needed to increase the rate of interception of hypersonic missiles. European SBMEW is still in development. The multinational Development Initiative for a Space-based missile early-warning architecture II (ODIN'S EYE II) will provide a European space-based missile early warning architecture addressing ballistic, hypersonic and anti-satellite (ASAT) threats, linked to TWISTER for Timely Warning and Interception with Space-based theatre surveillance (European Commission, 2023, p. 1; PESCO, 2024, p. 1). Without a European SBMEW, a defender would rely on national early warning chains, which raise latency and limit cueing for long-range intercepts and cross-border engagements.

Interceptor development for hypersonic threats is underway. The Hypersonic Defence Interceptor System (HYDIS) concept phase aims to select a European counter-hypersonic concept or family of concepts, maturing propulsion, agile guidance, terminal seekers, and AI-assisted engagement planning, with a development phase around 2030 and an in-service date near the 2035 horizon (OCCAR, 2024). In parallel, the Hypersonic Defence Interceptor

Programme (HYDEF) develops an endo-atmospheric interceptor concept for high-velocity aerial threats, tied to TWISTER and funded by the European Defence Fund (OCCAR, 2025). These programmes are crucial for closing the gap against manoeuvring RVs and glide vehicles at high altitude and high velocity.

It must be noted that the mentioned SBMEW and Space-based interceptors projects all fall under the EU framework, being part of EDF or PESCO. ESSI does not represent an EU initiative, therefore the access to these projects could be denied because of concerns about sharing data with non-allied countries. Limits on the transfer of results and sensitive information to third States could undermine ESSI capabilities and effectiveness.

In any case, these developing European capabilities will take time to be integrated into a multi-layered air and missile defence. In the meantime, Europe should also put the focus on ramping up industrial production. Russian missile production outpaces European interceptor output (Hoffmann, 2025b, para. 36). Detailed open-source assessments point to a missile gap, with Russia outcompeting Europe in the conventional missile domain, forcing a rethink of interceptor stockpiles, launcher density, and industrial surge capacity (Hoffmann, 2025c, para. 31; Hoffmann, 2025b, para. 36). Arguments caution against missile defence at any cost that depletes budgets without a sustainable concept of layered defence and offensive strike options to suppress launchers (Hoffmann, 2025b, para. 43). The Golden Dome debate in the United States illustrates this risk, with ambition outpacing a sustainable concept of operations (Hoffmann, 2025a, para. 9). A better framing is understanding missile defence as part of deterrence by denial, where the shield complicates coercion and blocks quick wins even if a perfect shield remains impossible (Wachs, 2023, p. 4).

3. Command, Control and Interoperability

ESSI needs a battle management/command and control layer that treats sensors, C2 assets, and weapons as one integrated air and missile defence architecture with overlapping layers and domains (Arnold & Arnold, 2023, p. 3). The process must be perfectly linked from reconnaissance via command and control to the combat units, or the shield will leak at scale (Arnold & Arnold, 2023, p. 3). This applies to ground-based batteries, to airborne and maritime sensors, and to space-based cueing. It also applies to national and alliance networks that must speak a common language of data.

Hypersonic defence compresses time. Command and control for hypersonic defence needs drastically reduced tactical response time, lower latency across the network, and integrated C2 in battle management and communications from strategic to tactical levels (Thales, 2024, para. 6). C2 must support early warning, tracking, discrimination, and timely weapon

classification along the whole trajectory (Thales, 2024, para. 9). The network must exchange plot-level data and dynamically network sensors to sustain an accurate track file during manoeuvre (Thales, 2024, para. 11). Alignment between nations and services must improve or the engagement windows will close before the shooter loop completes (Thales, 2024, para. 15).

NATO already fields a backbone for this. The NATO Integrated Air and Missile Defence System (NATINAMDS) integrates the networking of sensors, command and control, and kinetic effectors for integrated air and missile defence across the Alliance (Wachs, 2023, p. 3). European programmes now aim to sharpen the common air picture within this backbone. A Super Recognised Air Picture is under development to deliver a richer, fused view for tactical and operational decision-making (Withington, 2025, para. 3). This matters for cross-border hand-offs and for sensor-to-shooter pairing across nations.

ESSI must anchor itself to that backbone. NATINAMDS is the only viable frame for standardised message sets, common data models, and federated fire control across borders (Wachs, 2023, p. 6). ESSI is not an operational initiative, network, or command-and-control system. Its systems must be connected to NATO IADS to be effective beyond national boundaries (Withington, 2025, para. 13). That connection should carry both classic air tracks and passive, low-probability-of-intercept contributions that help hold a hypersonic threat in track.

Poland's Integrated Air and Missile Defence Battle Command System (IBCS) path offers a practical model. IBCS provides any-sensor to any-shooter connectivity across distributed sensors and shooters and supports a real-time, dynamic common air picture for integrated air and missile defence (Debuglies, 2025, para. 6). The architecture is open-architecture and supports sensor-to-shooter pairing across systems and services, which is exactly the kind of cross-battery fire control ESSI members will need under NATO tasking (Debuglies, 2025, para. 16).

European C2 still has gaps to close. IAMD C2 remains a moderate gap until NATO fields a common operating system to the numerous disparate C2 nodes (Monaghan & Christianson, 2023, p. 9). Today's nodes mix standards, security domains, and vendor stacks. The fix is a common operating system, shared data schemas, and repeatable gateways that move validated tracks and engagement status across sovereign boundaries (Monaghan & Christianson, 2023, p. 23). Information-sharing networks must expand from research and technology to real-time cueing data, and exercises must stress those links under load (Monaghan & Christianson, 2023, p. 24).

Interoperability starts with a common doctrine and continues in software. Integrated air defence means overlapping layers across all dimensions, and it demands that legacy and new systems be knitted together by intelligent software solutions that translate, filter, and fuse data at speed (Arnold & Arnold, 2023, p. 3). This is where a European Connect-4 logic is emerging: connect sensors, connect command and control, connect effectors, and connect across NATO levels from tactical to strategic (Withington, 2025, para. 3). Each connection needs agreed interfaces, cyber protection, and service management; otherwise, the seams will become points of failure during a saturation attack.

Passive and multi-static feeds strengthen the picture. Passive radar, such as the VigilantEye Radar and Advanced - Next Generation (VERA-NG), is planned in several nations and is already used by European militaries; its value grows when fused into NATINAMDS to help maintain track on low-observable or emitting-constrained targets (Withington, 2025, para. 12). Plot-level fusion that blends passive detections with active radar and space-based cues reduces false tracks and raises engagement quality (Thales, 2024, para. 11). That fusion should sit close to the weapon assignment logic to keep the loop short.

Rules and authorities matter as much as hardware. The network will falter if legal limits on engagement authority block cross-border shots. Integrated air defence requires pre-agreed authority chains, shared threat evaluation criteria, and rules of engagement that accepts cross-border engagements under a common plan (Arnold & Arnold, 2023, p. 3). Training and exercises must stress interoperability and putting military doctrine into practice (Monaghan & Christianson, 2023, p. 23–25).

Interoperability issues may arise when integrating Arrow 3, the layer on which ESSI is relying in case of a hypersonic threat. The system currently lacks interoperability with NATO systems (Wachs, 2023, p. 6). NATO has specific procedures to judge the interoperability of newly procured systems, but this would require approval from Israel and the United States and the release to the Alliance of sensitive Arrow data. Their willingness to provide that information remains uncertain, which could delay ESSI integration and limit its role inside the NATO IAMD layer (Wachs, 2023, p. 6).

Industrial and political choices feed back into C2. Fragmented procurement increases the number of bespoke interfaces and widens the work of integration teams. A focus on common/open architecture, common data models, and standardised tactical messages would save budget and time by design (Monaghan & Christianson, 2023, p. 25). The aim should be a modular approach inside NATINAMDS where new sensors, shooters, and tools plug into a known interface set and contribute to the Super Recognised Air Picture.

The direction of work is clear. European integrated air and missile defence needs a common BM/C2 layer that pulls SBMEW cues, national radars, passive sensors, and alliance feeds into a shared picture, then performs threat evaluation and weapon assignment at speed (Thales, 2024, para. 6). NATINAMDS provides the frame. ESSI provides the political lift and the kit. IBCS-type approaches show the mechanics of any-sensor to any-shooter. If the C2 gap is addressed through a common operating system to the numerous disparate C2 nodes, the shield will gain the reaction time it needs (Monaghan & Christianson, 2023, p. 9).

Conclusion

The European Sky Shield Initiative was examined as a response to drone saturation, cruise and ballistic missiles, and new hypersonic threats, asking how it can adapt, advance EU strategic autonomy, and keep full interoperability with NATO IAMD. The paper argued that a shield linking space-based missile early warning, a common battle management/command and control structure, and missile interceptors would cut decision time and raise European deterrence.

The threat picture shows mass low-cost drones, intensified Russian conventional missiles production, and hypersonic and manoeuvring ballistic systems compress decision cycles and stress upper-tier defences. Current capabilities add layered interceptors and point defence, but limits in stockpiles, costs, command arrangements, and interoperability persist.

NATO Integrated Air and Missile Defence System provides the backbone, while European programmes such as ODIN'S EYE II, TWISTER, HYDIS and HYDEF can move ESSI from a procurement club to an integrated air defence architecture, if legal authorities, data-sharing and a common operating system close the gap across sovereign boundaries.

The implications for European air and missiles defence are clear: bundle procurement, use EU-level borrowing to accelerate production, expand layered sensors and passive feeds, and adopt any-sensor to any-shooter approaches anchored to a Super Recognised Air Picture. Looking ahead, anchoring ESSI to NATINAMDS while accelerating SBMEW and interceptor development can deliver a resilient, interoperable, and autonomous European sky shield for deterrence.

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