

Transforming Joint Air and Space Power

THE JOURNAL OF THE JAPCC

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Deterrence in the Multi-Generational Battlespace

From Westphalia to Hybrid Warfare





INTEGRATED AIR POWER:

STRENGTHENING ALLIED DEFENSE AND CONNECTING
THE BATTLESPACE WITH UNMATCHED CAPABILITIES



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Editorial

Welcome to the 41st edition of the JAPCC Journal. As the Alliance navigates a security landscape defined by rapid technological shifts and geographic expansion, with crisis in Eastern Europe and the Middle East, our role in fostering innovation and interoperability has never been more critical.

For the first time in our history, the JAPCC has established an Annual Theme to focus our research, publications, and our flagship 2026 Joint Air and Space Power Conference: *Air Power at the Edge: Securing NATO's New Frontiers*. This theme takes to heart NATO's 360-degree approach, an approach that transcends geographic and political boundaries; it explores the 'edge' of our conceptual, digital, and cognitive boundaries. Our Chief of Staff, Colonel Kevin 'Tread' Anderson, provides a comprehensive introduction to the theme later in this edition, articulating the shift from reactive scan to proactive exploration of emerging threats, from the High North to the Indo-Pacific and into near space.

To identify and analyse Air Power's edge, it is our honour to feature leadership perspectives on Alliance cohesion from Lieutenant General Hinds, Commander of AIRCOM, and General Neumann, the German Air Chief. Complementing these operational Air Power perspectives, the CFSpCC Chief of Staff highlights the growing importance of the vertical frontier.

The articles in this edition explore readiness and technology at the limits of defined Air and Space Power. We draw on observations from both recent and historical conflict to identify implications for NATO deterrence and defence in modern conflict. Taking a comprehensive view of warfare in the post-Westphalian era, one author examines the

evolving character of warfare viewed through a multi-generational lens, and highlights the paradox of high-technology drones operating above trench warfare. With a view towards contemporary trends, two of our Combat Air experts assess challenges and opportunities posed by glide bombs in an era of increasingly denied air environments. At the tactical level, we explore gaps and developments in software-defined radios, tactical data links, and effects-as-a-service, questioning whether our current capabilities and training truly align with the demands of the future fight.

Several JAPCC authors and contributors analyse integration and preparation across domains; the convergence of SEAD and CEMA, and the utility of wargaming to refine targeting processes. Finally, recognising that the human mind remains our decisive advantage, this edition addresses the development of cognitive resilience and accelerated skill acquisition, ensuring that our personnel are prepared for the demands of the modern cognitive frontier.

The JAPCC remains committed to looking past the smoke of current conflicts to identify the embers of future challenges. We invite you to join us in pushing conventional limits and finding the edge, both within these pages and at our forthcoming conference, as we collectively define the future of NATO air and space power.

Vito Cracas

Colonel, ITA AF
Assistant Director, JAPCC



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Imprint

**Transforming Joint Air & Space Power:
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Purpose

The JAPCC Journal aims to serve as a forum for the presentation and stimulation of innovative thinking about strategic, operational and tactical aspects of Joint Air and Space Power. These include capability development, concept and doctrine, techniques and procedures, interoperability, exercise and training, force structure and readiness, etc.

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Cover Illustration: The X-37B orbital test vehicle arcs above the Earth, reflecting speed, reach, and the growing integration of air and space power. Its ability to operate flexibly across different orbits reinforces the importance of agility, responsiveness, and global perspective in modern joint operations. Aligned with JAPCC's mission, the image highlights the evolution of joint air power and the expanding role of space in supporting future-ready, multi-domain operations.



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A Norwegian F-35 shadows a Russian military aircraft, reflecting the vigilance and readiness required to defend Allied airspace every day.

Sense, Make Sense, Act

Adapting Air Power for Air Defence

By Lieutenant General Jason T. Hinds,
Commander, Allied Air Command and Director, JAPCC

It is a privilege of a lifetime to assume command of Allied Air Command (AIRCOM) and serve as Director of the Joint Air Power Competence Centre (JAPCC). As I look across this Alliance, from our newest members in the High North to the alert pads of the Southern Flank, I am struck by the dedication, leadership, and professionalism that our airmen bring to their units every single day. To everyone in this command, thank you. You are the shield of this Alliance.

I recognise that we do not have the luxury of easing into this new chapter. This is the most consequential time to serve in this command since the Cold War. The era of crisis management has ended; the era of collective defence is here. The threats we face, including

lethal unmanned systems, militarisation of space, and renewed high-intensity state competition, require us to eliminate complacency.

My guidance to this command is clear: NATO AIRCOM must continue to rapidly adapt to this new threat environment and work together as Allies and partners to remain ready for the high-end fight. Our mission is to deliver unparalleled allied Air and Space Power to deter aggression, and if deterrence fails, to win decisively. As airmen in charge of Air Command and Control, we are responsible for making the best use of Air and Space Power across SACEUR's area of responsibility (AOR) to achieve strategic and regional effects. We must have a clear vision, understand



© AIRCOM

Lieutenant General Hinds (right) takes his place at the helm of Allied AIRCOM, as the colours and flags of the Alliance underscore the weight of command and the beginning of a new chapter.

our priorities, and address the challenges of today and tomorrow with urgency and resolve. Our mandate is simple: 'Fight Tonight, Fight Tomorrow, and Fight Together'.

The Strategic Anchor: Priorities and Urgency

AIRCOM's five foundational priorities remain unchanged: Counter Anti-Access/Area Denial (A2AD), Integrated Air and Missile Defence and Ballistic Missile Defence (IAMD and BMD), Air Command and Control (C2), Intelligence, Information and Data Sharing, and Agile Combat Employment (ACE). These priorities establish the structural basis that enables us to provide unparalleled Air and Space Power for the Alliance.

Although these priorities remain constant, the pace of implementation will accelerate. They are now daily operational imperatives rather than theoretical constructs. While we maintain comprehensive 360-degree threat awareness, the need for transformation is most urgent on the Eastern Flank. The operational environment in the East has fundamentally changed, requiring a corresponding adjustment in our posture. Enhanced Vigilance Activity (eVA), Eastern Sentry, remains one of SACEUR's highest priorities. We must capitalise on the

momentum generated by this activity to deliver the defence design required for the Alliance.

The Great Transition: From Policing to Defence

For decades, we have relied on Air Policing, a peacetime mission designed to identify and escort non-hostile aircraft. That era is ending. We are now in a transition from Air Policing to Air Defence. I see eVA Eastern Sentry not just as a response, but as the primary vehicle to enable this transition into a true warfighting posture.

This is more than a change in semantics; it constitutes a doctrinal revolution. Air Policing is about law enforcement; Air Defence is about warfighting. The events of September 2025, where Russian drone incursions challenged the sovereignty of Allied airspace in Poland and Latvia, served as a wake-up call. They highlighted that in a hybrid environment, the distinction between peace and crisis is blurred. We responded rapidly with the launch of eVA Eastern Sentry, but now we must replace our reflexive response with a proactive strategy.

We are seeing progress. On 1 January 2026, the Croatian Air Force officially assumed full responsibility for its airspace within the NATO framework, using their newly



B-1B Lancers fly above historic statuary, pairing modern long-range strike power with the enduring legacy of defence and deterrence that underpins the Alliance.

operational Rafale fleet. This seamless integration of national capability into the Allied network is the model we must replicate. To scale this effort, we are undertaking, under SHAPE leadership, a comprehensive rewrite of Standing Defence Plan (SDP) 11000 to align national and NATO plans, informed by initiatives such as the Layered Counter-UAS (LCI-X) beacon project. By implementing eVA Eastern Sentry and updating our defence plans, we are moving toward a posture of ‘Deterrence by Denial’.

Bending the Curves

As we operationalise this shift, we must address four important ‘curves’ that define our readiness:

- **The Cost Curve:** We must reverse the cost imposition strategy currently favoured by our adversaries. We cannot sustain a model where we fire multi-million-dollar interceptors at cheap, disposable drones. We must integrate ‘high-low’ mix effectors to ensure financial sustainability in a prolonged conflict.
- **The Production Curve:** Air Power requires both mass and precision. We must work with industry to ensure we have the capacity and readiness to produce munitions and platforms in reserve and on demand.
- **The Permission Curve:** The speed of modern warfare does not allow for burdensome political approval cycles during an engagement. We must anticipate and adapt our Rules of Engagement (ROE) and political approval to enable Air Defence at the tactical edge.

- **The Innovation Curve:** We must develop and use Artificial Intelligence (AI) and automation to accelerate decision speed and adaptability, keeping us inside the adversary’s loop and on the right side of the cost curve.

Domain Awareness: Sense, Make Sense, Act

To fight effectively, we must master the cycle of Sense, Make Sense, and Act.

- **Sense:** We are integrating Multi-Domain Operations (MDO), unifying not only Land and Air components but also LANDCOM and MARCOM to enable awareness from the seabed to space. This involves leveraging Over-the-Horizon (OTH) technology, the Alliance Persistent Surveillance from Space (APSS) initiative, and passive detection systems.
- **Make Sense:** This is the role of C2. We are deploying tools like the Allied Exchange Environment (AXE) and Maven Smart Systems (MSS) to prioritise data sharing, fusion, and automation. We must synthesise vast amounts of sensor data into a coherent picture that allows commanders to understand the battlespace instantly.
- **Act:** We must deliver effects through a layered approach. This includes the high-low mix, integrating capabilities such as Switchblade drones onto MQ-9 Reapers to increase lethality while reducing risk to manned platforms. Acting means closing the kill chain in seconds, not minutes.



Allied aircraft fly in close formation above the clouds, reflecting the integration, reach, and shared readiness that define NATO Air Power today.

The View from JAPCC: Securing the Edge

I am proud to serve not only as AIRCOM Commander but also as Director of the JAPCC. These dual responsibilities directly reinforce each other; AIRCOM is ready to fight at any moment, while JAPCC relentlessly anticipates the future. Our Annual theme, Air Power at the Edge – Securing NATO’s New Frontiers, decisively applies the Sense, Make Sense, Act framework. JAPCC proactively identifies emerging challenges in the Arctic and Indo-Pacific, develops actionable roadmaps for Autonomous Collaborative Platforms, and codifies these innovations into NATO doctrine.

It is clear from this Journal that JAPCC has been hard at work. Following this article, Lieutenant General Holger Neumann, Chief of the German Air Force, outlines how national air forces are integrating into this

collective defence architecture, and Colonel Jonathan Whitaker, Chief of Staff, CFSpCC, explains how we are operationalising Space as a true warfighting domain.

Conclusion

Our nations demand excellence from AIRCOM, and I have full confidence that together we will continue to set the standard. Whether shifting from Air Policing to Air Defence to secure the East, or exploring the ‘edge’ of Space and Cyber to secure the future, our mission remains singular. We must be an AIRCOM team trained and ready to deliver decisive Air and Space Power for the Alliance, anytime, anyplace.

I look forward to our time together as we stand ready to ‘Fight Tonight, Fight Tomorrow, Fight Together’. ●



ABOUT THE AUTHOR

By Lieutenant General Jason T. Hinds

Commander, Allied Air Command and Director, JAPCC

Lieutenant General Jason T. Hinds serves as Commander, US Air Forces in Europe, Commander, US Air Forces Africa, Commander, Allied Air Command at Ramstein Air Base, Germany, and Director of the Joint Air Power Competence Centre in Kalkar, Germany. In these roles, he leads the air component to US European Command and US Africa Command, delivering full-spectrum air power across an area of responsibility spanning 104 nations throughout Europe, Africa, parts of Asia, and the Arctic and Atlantic regions, an area that includes more than a quarter of the world’s population and

economic output. Commissioned through Florida State University in 1996, he was a distinguished graduate of Joint Specialized Undergraduate Pilot Training at Vance Air Force Base in 1997 and the F-15 Replacement Training Unit at Tyndall AFB in 1998. His career includes command of the 1st Fighter Wing and an F-22 squadron, and service as an F-22 instructor pilot and flight examiner, F-15C instructor pilot and weapons officer, and US Air Force Weapons School instructor. Prior to his current assignment, he served as Deputy Commander for US Air Forces in Europe and US Air Forces Africa.

Ready. Fight. Win. Together. In Air and Space

Forging a New Warfighting Mindset for Air and Space Power

By Lieutenant General Holger Neumann,
Chief of the German Air Force

Introduction

I had the honour to participate in, and deliver a keynote at, the annual Joint Air & Space Power Conference. Hosted by the Joint Air Power Competence Centre (JAPCC), the event once again proven itself to be an internationally recognised open discussion forum on relevant issues to the Alliance.

This year's conference was particularly striking as we celebrated the 20th anniversary of the JAPCC. Since its foundation, the JAPCC has played a vital role as NATO's first Centre of Excellence, consistently demonstrating expertise, foresight, and commitment in advancing Air and Space Power within the Alliance.

The conference theme, 'Disrupting Dominance: The Future of Air Superiority?', was the perfect focus. It was inspiring to witness the exchange of ideas, panel discussions, and informal talks that deepened our collective understanding.

What I took away from these vital discussions is that we truly stand at an inflection point. Technological

acceleration, geopolitical instability, and the emergence of both known and novel threats necessitate a different approach to thinking about air and space power.

The relevance of air and space power has become more apparent than ever. To meet this challenge, I have defined navigation points for shaping the future of the Luftwaffe:

The Evolution of Air Warfare

Air warfare is transforming, not just in terms of platforms, but in the very concept of operations. It is being re-shaped by technological advances, new adversarial tactics, and the multi-domain nature of modern conflicts.

We face a host of urgent threats. The rise of tactical ballistic missiles, first-person view (FPV) drones, one-way



attack unmanned aerial vehicles (UAV), hypersonic effectors, and glide bombs is among the most pressing. We observe mass saturation attacks and tactics designed to overwhelm our sensors and air defences through the sheer quantity and speed of engagement.

Simultaneously, we face increasingly integrated Anti-Access/Area Denial (A2/AD) environments that combine surface-to-air missile systems, cyber operations, and electronic warfare. These integrated threats aim to blind, deafen, and isolate our forces, rendering our traditional strengths vulnerable. Adding to the complexity is the increasing militarisation of the space and

cyber domains, as adversaries are now targeting our 'eyes and ears', our satellites, sensors, and communication links, to paralyse command and control (C2) networks and hinder our kill chain. And, of course, we face the challenge of dealing with advanced platforms, including four point five and fifth-generation fighter aircraft, that can rival our current capabilities.

What this means is that our long-held assumptions of technological overmatch and freedom of manoeuvre are no longer guaranteed. The 'sanctuary' of high altitude and the 'invisibility' of stealth are being systematically challenged. The integration of low-cost, high-volume threats with high-end, exquisite systems is the central dilemma we must now solve.

In this context, merely observing current conflicts is insufficient. There is no 'copy-paste' strategy for future warfare. While conflicts such as Ukraine provide valuable insights into attrition warfare, drone usage, and the power of resilience, their lessons must be interpreted with caution. It is not the only lens through which we should view future (air) warfare. Overgeneralisation leads to dangerous misjudgements. We must exercise caution in drawing conclusions, as each conflict has its own unique context, geography, and strategic implications.

'What this means is that our long-held assumptions of technological overmatch and freedom of manoeuvre are no longer guaranteed. The "sanctuary" of high altitude and the "invisibility" of stealth are being systematically challenged.'

For Germany and its allies, the implications are clear: Air power's role as the first responder makes it uniquely indispensable. This remains true.

But recognising this evolution is not enough. This complex, lethal, and rapidly evolving threat landscape demands more than just observation; it requires introspection. This leads to difficult questions we must ask ourselves.



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To protect the skies over Germany, we rely on various air defence capabilities, such as the Patriot surface to air missile system.

1. Ready to Fight

The first hard question we must ask ourselves is simple: Are we ready to fight?

For decades, many of our nations have operated their militaries under the assumption of 'wars of choice', limited operations conducted under strict political constraints and often far from home. This has shaped an entire generation of military leaders, policies, and mindsets. That era is ending.

The next conflict may not be optional. It will likely be brutal, fast-paced, and deeply contested. It will not allow for slow mobilisation or months-long ramp-ups. The time to prepare is not tomorrow. It is now.

- Peacetime regulations are still in place, enabling hybrid actors to exploit legal loopholes and inhibit our ability to respond swiftly.
- Logistics and procurement systems are optimised for cost efficiency rather than wartime resilience and effectiveness.
- Stockpiles of ammunition and spare parts remain limited.

- Critical components of our defence infrastructure have been outsourced or hollowed out under the guise of peacetime optimisation.

These tangible shortfalls in stockpiles, logistics, and legal frameworks are not independent failures. They are the physical symptoms of a deeper, more corrosive problem: the erosion of the warfighting mindset is just as concerning. In a military culture where 'upon-action' legal reviews, risk aversion, and budget constraints often dominate decision-making, we risk becoming unfit for the realities of high-intensity warfare.

Readiness is not an end state. It is a continuous process, and our response must be multidimensional:

- Raise awareness among the public, political leaders, and military personnel that war is not an abstract threat. It is a real and present danger.
- Rebuild readiness, not just in hardware, but in mindset and doctrine.
- Sustainability over efficiency: logistics systems must be built for endurance and effectiveness, not just cost savings.

- Military exceptions in law and policy, especially in the ‘grey zone’ between war and peace, must be expanded to allow faster more decisive action.

2. Set Up to Win

The second critical question is: Are we structured and equipped to win?

Too often, air power is misunderstood, even within our own defence establishments. It is sometimes dismissed as merely an impervious defensive shield or a supporting domain for tactical strikes. UAV and air defences dominate the headlines, while the broader spectrum of air and space operations is frequently overlooked.

This is a strategic mistake.

Air Power is about achieving and maintaining air superiority, and, if deterrence fails, striking deep into enemy territory, and supporting ground and maritime forces. In a peer conflict, it must do all this simultaneously, while a capable opponent actively challenges every domain. In the hands of a capable force, Air Power projects strength, creates freedom of action, and dictates tempo.

Consider the contrast between two recent conflict environments:

- In Ukraine, we see the intense use of a high number of mass-produced, and low-cost drones, stand-off weapons, capable electronic warfare, and layered ground-based air defences. We see a war fought mainly on the ground, with neither side achieving air superiority.
- In the Middle East, during the conflict between Iran and Israel, we saw classical air superiority, long-range precision air strikes, and electronic warfare playing decisive roles. We witnessed what Air Power can achieve.

Both offer lessons, but neither provides a complete blueprint. Instead, they highlight the diversity of modern conflict and the flexibility Air Power must retain.

This is precisely where the danger of overgeneralisation lies. The headlines from Ukraine, dominated by

drones and layered ground-based air defences, risk reinforcing the same narrow, defensive mindset that we developed during decades of crisis response operations. This focus on defensive shields, reconnaissance, and support tasks is a dangerously limited view.

Air Power is not an accessory to Land Power. It is a potent instrument in its own right. At its core, Air Power is about reach, speed, precision, and dominance. It enables strategic and decisive strikes, rapid mobility, multi-domain integration, and deep effects far beyond the front lines.

It is important to emphasise that Air Power is not always and exclusively about defence. It is about deterrence and dominance. It is about shaping the fight, ideally right from the very beginning.

To win, our air and space forces must be capable of operating across this full spectrum. This means mastering high-end, peer-level operations and, at the same time, possessing the capacity and resilience to defeat high volumes of low-quality, inexpensive air assets.

- Offensive capabilities must be prioritised. Deterrence is only credible if backed by the ability to strike.
- Strategic communications must clarify the value of Air and Space Power, not just to the public, but also to joint force planners and decision-makers and potential adversaries.
- Training and doctrine must evolve to match new threats while retaining the core principles that have historically defined air superiority.

Let us be clear: Winning is not one option among many. In peer-level warfare, winning is the only option.

3. Win Together

The third and most strategic question is: Are we prepared to win together?

Modern warfare is multi-domain by nature. Cyber, Land, Sea, Air, and Space operations are interconnected. Yet too often, we see stovepiped thinking and national unilateralism undermining Alliance cohesion.



By providing robust air mobility, German A400M aircraft underpin NATO's ability to project, sustain, and integrate Air Power across the Alliance.

In an era where adversaries move with agility – especially in the use of rapidly scalable technologies like drones, being slow, fragmented, or bureaucratically paralysed compromises desired effects.

While others scale up drone production or accomplish innovation cycles in weeks, we are still navigating tendering procedures, which slows us down significantly.

While others field innovations rapidly, we are debating procurement laws without bringing the required equipment into use. This procedural paralysis is not an accident; it is a choice. We have built a procurement and innovation ecosystem designed to optimise peacetime efficiency and eliminate financial risk. Our adversaries, in contrast, have built an ecosystem designed to act at speed, accepting failure and cost overruns as the price of rapid capability. This fundamentally misaligned risk culture is now a critical vulnerability.

The real test is not whether we can fill warehouses. It is whether we can develop, produce, integrate, and scale, even under pressure, new technologies in a short time, coordinate efforts within the Alliance, and adapt faster than our adversaries.

To that end, we must achieve a common understanding within the Alliance to:

- Invest in innovation and processes, not just in platforms.
- Rebuild industrial resilience so that we can shift from peacetime to wartime production when needed.

- Strengthen interoperability across platforms commands, and coalitions.
- Commit to common standards within NATO and the European Union, ensuring seamless integration across forces.
- Treat industry as a strategic partner, not merely a supplier, fostering the civil-military cooperation crucial for success.

We must resist the temptation to retreat to unilateral solutions. Cohesion is a force multiplier, and fragmentation weakens us politically, militarily, and industrially. A unified Air Power strategy, one that is joint, combined, agile, and forward-looking, is our best chance to deter and, if necessary, to defeat any adversary. NATO Air and Space Power must be credible to deter a potential opponent.

If deterrence fails, we must be ready mentally, structurally, and operationally, to fight, knowing that winning is the only option. This means forces must be combat effective immediately, to fight tonight. That is the standard we must train for, plan for, and equip ourselves for.

Conclusion: Stand Ready. Think Forward. Act Together.

In NATO's future conflicts, air and space superiority will be the decisive factor. This requires both credible defensive and offensive capabilities, and the assured use of our space-based assets is crucial for enabling our



Only through readiness, integration, and collective resolve can NATO Air Power fight and win together.

operational success. The lesson from high-end conflicts is clear: Offensive air capabilities are the most effective deterrent. They depend on the ability to suppress enemy air defences, strike deep, and project force across borders and domains, quickly and decisively.

Achieving this 'Win' is impossible without first being 'Ready', forging a new warfighting mindset that sheds peacetime risk aversion. And this capability is unless

we do it 'Together', with the industrial resilience and Alliance-wide unity to innovate, scale, and integrate faster than our adversaries. These three imperatives are inextricably linked.

Let us rise to the challenge. Let us think forward, stand together, and ensure that when the moment comes, we are not only ready to fight, but prepared to win together. ●



ABOUT THE AUTHOR

Lieutenant General Holger Neumann
Chief of the German Air Force

Lieutenant General Holger Neumann joined the Bundeswehr in 1988 and completed his basic military service with Airborne Ranger Battalion 253 in Nagold. Following officer and flying training, he served as TORNADO fighter pilot with Fighter Bomber Wing 34. After graduating from the General Staff Officer Course, Neumann held posts at the Federal Ministry of Defense as well as at NATO SHAPE in Mons. In 2013, he completed Eurofighter weapon system training and served as Deputy Commander of Tactical Air Wing 74 in Neuburg, including a deployment to

Afghanistan. From 2015 to 2017, he commanded Tactical Air Wing 74 before returning to Berlin as Deputy Spokesperson of the Federal Ministry of Defense. Between 2018 and 2021, Neumann served as Director of Training and Education at the Bundeswehr Command and Staff College in Hamburg. He then assumed the post of Deputy Chief of Staff 1 at the German Air Force Headquarters and later served as Commander Flying Units at the Air Force Forces Command. In May 2025, he was promoted to Lieutenant General and appointed Chief of the German Air Force.

Regaining the High Ground

A NATO CFSpCC Perspective

By Colonel Jonathan Whitaker, Chief of Staff, NATO CFSpCC

By Major Luke Stensberg, US Space Force, JAPCC

Introduction

Space is now a decisive theatre of operations for the Alliance. Once treated primarily as a benign enabler of activity in other domains, it is now actively contested and increasingly central to the success or failure of joint operations. For decades, NATO forces operated on the assumption that access to space-based capabilities, including satellite communications (SATCOM), positioning, navigation, and timing (PNT), and space-based intelligence, surveillance, and reconnaissance (ISR), would remain reliable and largely uncontested. That assumption shaped how the Alliance planned, fought, and invested. Adversaries did not share it. They observed NATO's growing dependence on space-enabled effects and invested in capabilities designed to hold them at risk.

In February 2025, as a visible expression of this paradigm shift, NATO established the Combined Forces Space Component Command (CFSpCC) as a Theatre Component Command (TCC) under Allied Air Command (AIRCOM) in a trial structure. Commanded by the dual-hatted Commander of AIRCOM, CFSpCC marked the Alliance's transition from being primarily a consumer of space data, products, and services (DPS) to an organisation able to plan, prioritise, and integrate space effects for the joint fight. Rather than assuming space support will simply be available, CFSpCC provides the mechanism through which Allied contributions are orchestrated, synchronised, and directed in support of multi-domain operations (MDO), even under sustained competition.

This article examines how CFSpCC responds to the challenges of maintaining NATO's freedom of action in the space domain. It explains why NATO's historic

Close approaches between satellites, whether deliberate or not, underscore how the space domain is becoming more congested and contested.

coordination model is no longer sufficient, how the transition to a component-level command enables space effects to be planned and employed deliberately, and what must still be done to ensure the Alliance can deter aggression and prevail when space is contested rather than assumed.

From the 'End of History' to a Contested Domain

The domain's evolution is rooted in the post-Cold War strategic environment. After 1991, high-intensity conflict in Europe was widely viewed as unlikely. Defence budgets declined, and space capabilities were developed in an environment where access was rarely challenged. During operations in the Balkans, the Middle East, and Central Asia, space-enabled services became an assumed condition of warfare. SATCOM connected headquarters and deployed forces, satellite imagery delivered unprecedented situational awareness, and Global Navigation Satellite Systems (GNSS), such as GPS, underpinned precision strike and logistics. These capabilities became deeply embedded in NATO's way of modern warfare.

Near-peer competitors studied these campaigns closely. They recognised that space was not merely supportive but foundational to NATO's operational effectiveness, and developed anti-access and area denial (A2AD) postures that extended into the Space Domain.¹ Today, counterspace activities spanning electronic warfare, cyber operations, long-range fires, and dedicated counterspace systems can disrupt PNT, SATCOM, and space-based ISR, and target vulnerable ground infrastructure.

By 2019, the rapid growth of national and commercial space systems, combined with increasingly visible denial and disruption, made the status quo untenable.² As the former acting Commander of AIRCOM and CFSpCC, and current Deputy Supreme Allied Commander Europe (SACEUR), Air Chief Marshal Sir Johnny Stringer, observed, it had become essentially 'counterfactual' to deny that space required treatment as an operational domain in its own right.³ The challenge for NATO was no longer whether space was contested, but how the Alliance would organise itself to command, integrate, and defend its use of the domain.

From Coordination to Command

Before the establishment of CFSpCC, NATO's approach to space was largely one of coordination. Space equities sat in specialist cells that advised other headquarters, but space activities were not adequately prioritised, tasked, or synchronised as a domain. Space functioned as an enabler, but not as a peer theatre component responsible for shaping operational outcomes.

The stand-up of CFSpCC marks a deliberate break from that model. As a theatre component, CFSpCC exercises command and control (C2) over NATO-assigned space forces and capabilities, provides guidance to SACEUR on the employment of the effects within the domain, and synchronises national and commercial contributions into the Allied fight. Though embedded in AIRCOM, SACEUR has delegated to COM CFSpCC the same component level responsibilities as major NATO TCCs to deliver operational effects, not merely situational awareness.

'NATO does not own satellites or command spacecraft in orbit. CFSpCC's value lies in brokering and orchestrating effects from national and commercial contributors.'

However, as SACEUR's operational requirements for space continue to expand, CFSpCC must evolve accordingly. Theatre-level tasks require more than an operations centre; they demand a component staff able to plan, synchronise, assess, and sustain space effects across all joint operating areas. Establishing a credible space battle rhythm will ultimately require a staff construct comparable to other component commands.

Against this backdrop, CFSpCC has focused on three priorities that underpin the transition from coordination to command: establishing coherent space C2, strengthening space support to operations and space-based ISR, and developing robust Space Domain awareness (SDA) as a core NATO capability.



The CFSpCC consists of 40 personnel embedded across seven operational-level commands within the NATO Command Structure, with projected growth up to 73 personnel.

Priority 1: Establishing Space Command and Control

The first priority is to establish credible C2 for space operations at the theatre level. The stand-up of the NATO CFSpCC within AIRCOM empowers the Commander with the authorities of a TCC for the Space Domain. While the Commander of AIRCOM also serves as the Commander of CFSpCC, this role is executed under a distinct space mandate and supported by a dedicated cadre of space professionals. Co-location with AIRCOM enables the use of mature infrastructure and facilitates multi-domain integration, while the CFSpCC construct ensures that space effects are planned, prioritised, and directed with the authority and coherence expected of a theatre component, rather than treated as a subordinate function.

While NATO does not assume command over national capabilities, CFSpCC, together with the wider NATO space enterprise, develops a Combined Joint Statement of Requirements (CJSOR) aligned with SACEUR's operational phasing. This enables nations and partners to present space forces and effects in step with the Alliance's multi-domain battle rhythm across multiple joint operating areas.

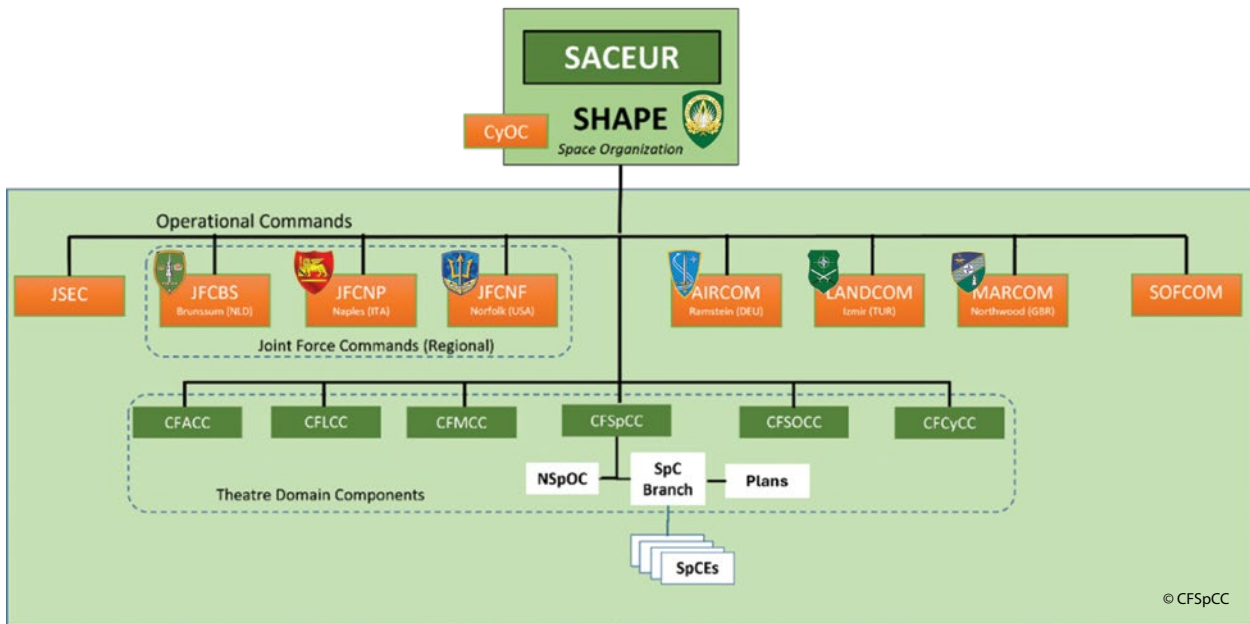
A critical enabler of this model is the routine integration of space into joint command structures. Space Coordination Elements (SpCEs) embedded within

JFCs and other TCCs extend CFSpCC's C2, ensuring that space effects are planned, synchronised, and assessed alongside other joint functions. This shifts space from reactive coordination to deliberate integration at the outset of any operational planning effort. It is of primary importance that space enablers are planned from the beginning to fully realise the combat edge that they provide.

It is worth noting that from a command perspective, the growing availability of space-enabled capabilities increases both opportunity and complexity. Proliferated architectures, particularly in Low Earth Orbit (LEO), provide greater resilience and capacity, but only if their effects are prioritised and synchronised through a coherent command framework. Unified space C2 is therefore not about owning satellites. It is about directing space-enabled effects in time, purpose, and scale in support of SACEUR's objectives. Only under such a framework can space be credibly commanded as a domain rather than merely coordinated as a support function.

Priority 2: Bolstering Operational Space Support and Space-Based ISR

The second priority is to strengthen operational space support (OSS) to the joint force along with space-based ISR. OSS encompasses the planning, coordination, and



A unified space command and control structure is critical for the Alliance, synchronising on-orbit activities with the rest of the terrestrial fight.

delivery of space-derived DPS that enable commanders to operate with confidence under sustained competition. This includes ensuring access to SATCOM, coordinated PNT effects, electromagnetic interference assessments, and space-based intelligence that underpins operational decision-making.

The NATO Space Operations Centre (NSpOC) is central to delivering this support. It is the Alliance's focal point for OSS, integrating national and commercial space inputs and translating them into operationally relevant outputs for intelligence, operations, and planning staffs across NATO. The objective is not to replicate national or commercial capabilities, but to ensure those capabilities are prioritised, synchronised, and delivered in a form that directly enables NATO MDO.

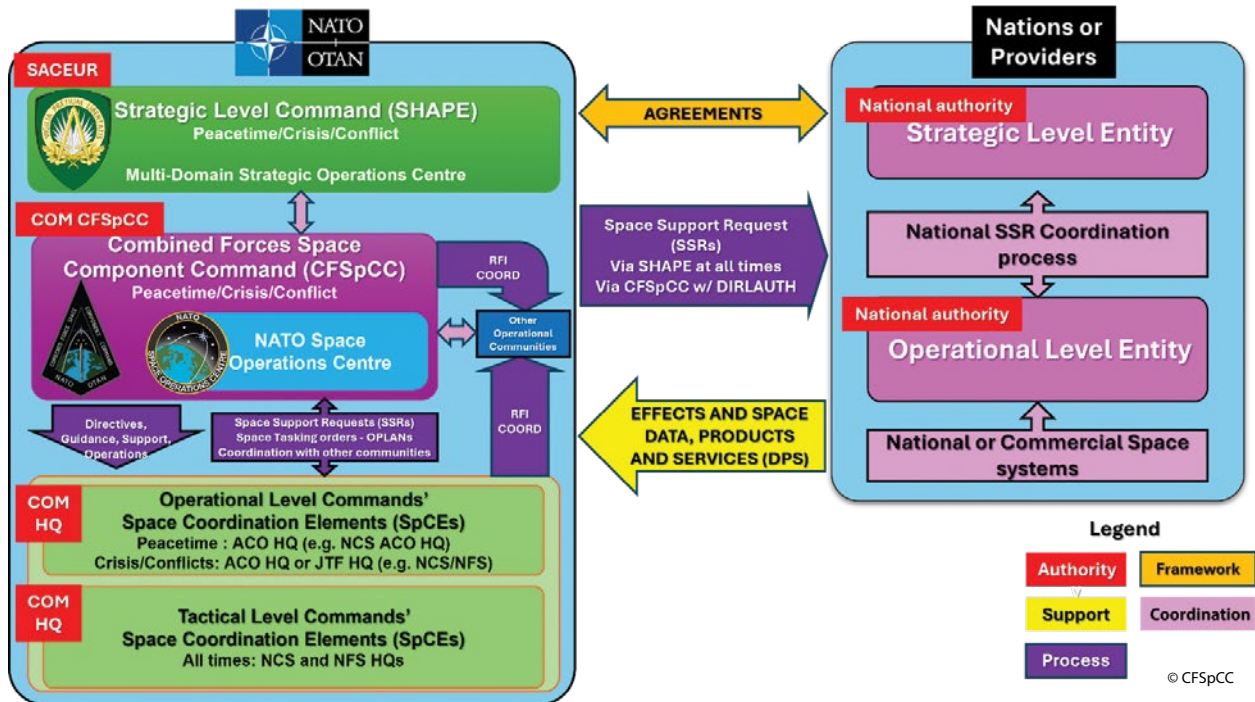
Space-based ISR is a critical contribution to the OSS construct. Alliance Persistent Surveillance from Space (APSS) is the primary mechanism through which NATO is strengthening its own space-based ISR posture. Delivered through a voluntary multinational contribution led by Luxembourg and supported by nineteen Allies, APSS is building a virtual constellation, Aquila, composed of national and commercial satellites and services that will provide persistent ISR, particularly in denied or high-risk environments. As APSS matures, the NSpOC will play an active role in coordinating, exploiting, and integrating APSS-derived outputs into NATO planning and execution. When fused

with other intelligence sources, these products support targeting, force protection, and scheme of manoeuvre across all domains.

Priority 3: Developing Robust Space Domain Awareness for NATO

The third priority is to develop robust space domain awareness (SDA) as a core NATO capability. SDA underpins the Alliance's ability to protect space systems, preserve freedom of action in the domain, and make informed operational decisions. NATO's approach to SDA has evolved from simple 'traffic management' to active threat characterisation. As adversaries deploy sophisticated counterspace capabilities, from ground-based jammers to co-orbital inspector satellites, NATO's priority is timely attribution. We must be able to detect, identify, and attribute hostile acts in space at the speed of operations.

To achieve this at scale, NATO has operationalised a federated model that bridges national and commercial data. A primary enabler is the US Joint Commercial Operations (JCO) cell. With NATO's transition to common funding for the JCO later this year, the Alliance will integrate a global commercial sensor network directly into the NSpOC. This non-classified layer allows for rapid, shareable early warning of adversarial activity that was



The diagram above demonstrates how agreements, support requests, and effects harmonise together to fuel OSS within the NATO Space Enterprise.

previously trapped behind national classification barriers. Ultimately, a credible SDA capability reinforces deterrence by demonstrating to any potential aggressor that their actions in the dark of space are visible, attributable, and part of the Alliance's collective defence calculus.

Translating Intent into Action: The Roadmap to Readiness

Credible deterrence means that the Alliance must fight through the contested Space Domain and deliver joint effects at scale. To achieve this through actionable deliverables, two primary efforts are of particular importance: the Mission Essential Task List (METL) and the Space Campaign Plan (CAMPLAN).

The METL establishes the baseline for mission success. It is a rigorous, bottom-up taxonomy that defines exactly what the Component must be able to do to meet SACEUR's requirements, from providing shared early warning to ensuring SATCOM resilience in a contested environment. By clarifying readiness against these specific tasks, the CFSpCC can provide higher headquarters and the North Atlantic Council (NAC) with an objective health check of the domain.

Supporting this is the Space CAMPLAN, which serves as a long-term roadmap. It harmonises disparate efforts, such as the Commercial Space Strategy, Space Domain Action Plan, and the APSS programme into a single, coherent timeline. More importantly, the CAMPLAN identifies the gaps where mission requirements outpace current resources.

As the CFSpCC matures, these efforts have exposed three critical enablers that must be addressed to ensure NATO maintains its high ground advantage:

1. Commercial integration,
2. Force structure and command relationships (COMREL), and
3. DDA Plans and policy alignment.

1. Commercial Integration: Capabilities, Not Satellites

NATO does not own satellites or command spacecraft in orbit. CFSpCC's value lies in brokering and orchestrating effects from national and commercial contributors, effectively serving as NATO's Space Commercial Integration Cell.



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SDA implies not only detecting and tracking objects on orbit, but also characterising their intent and potential impacts to Allied operations.

CFSpCC's philosophy for commercial integration is to be agile in contracting and flexible in capability integration through a NATO marketplace in order to rapidly deliver existing or prototype space data and effects directly to joint force users. This agility is a strength that will allow CFSpCC to evolve combat capability while operating from prototypes rather than awaiting perfect deliveries of systems of record. For NATO, the environment can be the system of record, but the data will continuously evolve. It is akin to the modern approaches the US Space Development Agency has taken, or those a company like SpaceX takes, with operational test and development cycles.⁴

2. Modernised Force Structure and COMREL

The most sophisticated technology is irrelevant without the human architecture required to exploit it. As former acting CFSpCC Commander, Air Chief Marshal Sir Johnny Stringer has noted, the return on investment in space depends entirely on the workforce capable of directing it.⁵ Currently, the CFSpCC operates in a trial structure, an arrangement designed to test the initial concept of a space component. However, the rapid expansion of the SDA mission, onboarding of complex ISR architectures like Aquila, and soon-to-be-delivered mission systems have pushed this provisional structure to its limit.

To move beyond coordination and achieve true C2, the CFSpCC must evolve into a full staff construct. A TCC cannot remain in initial operating capability; it requires dedicated S1-S10 directorates that operate at the same tempo as our Land, Maritime, and Air peers. Without this professional staff depth, the CFSpCC risks becoming a bottleneck rather than a facilitator for SACEUR's objectives.

This evolution is not merely about headcount; it is also about command relationships (COMREL). The forthcoming Space C2 Concept of Operations (CONOPS) will define the enduring authorities and workforce requirements needed to sustain a 24/7 space battle rhythm. This includes establishing the CFSpCC as a primary space intelligence node for NATO, ensuring that space-derived indicators and warnings flow directly to the NAC and frontline commanders alike. Realising this vision requires the Alliance to move past trial status and commit to a permanent, resilient force structure that reflects Space's status as a decisive operational domain.

3. DDA Family of Plans and Policy Alignment

Plans and policy can be either the ultimate enabler or the ultimate bottleneck. For CFSpCC to be effective, space effects must be hard-wired into the Deterrence and Defence of the Euro-Atlantic Area (DDA) family of plans, including through the Subordinate Space Plan



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Two operators at the NSpOC analyse recent launches and assess any implications to Allied operations.

(SSP). Ultimately, the NATO Defence Planning Process (NDPP) is only as good as the operational DDA plans that it resources. Therefore, CFSpCC and SHAPE are partnered to deliver phased campaign-focused plans, starting with the JFC plans, and then harmonising cross-JOA with a campaign-focused SSP. We are confident that these plans will form the basis of a real and actionable CJSOR and corresponding SHAPE Operational Requirements Statement that will unleash the NDPP to fully resource space at NATO.

‘Though embedded in AIRCOM, SACEUR has delegated to COM CFSpCC the same component level responsibilities as major NATO TCCs to deliver operational effects, not merely situational awareness.’

Planning effectiveness also depends on the speed and scope of information sharing. Modernising classification and releasability pathways remains essential to delivering space effects at operational tempo. The companion to classifications and releasability is the establishment of classified, special access facilities at AIRCOM and SHAPE, where the nations with the most sensitive capabilities can collaborate with NATO planners. We are developing mutually beneficial partnerships with USSPACECOM and the US Space Force as they fulfil their national guidance

to strengthen partnerships for collective space security, along with many other space-capable nations.⁶ Now we need the physical space to collaborate.

Finally, accelerated standardisation of space data and procurement, including a common-funded commercial SDA core picture, offers a practical means to reduce duplication while preserving national prerogatives. Together, these policy enablers determine whether NATO can translate space intent into sustained operational effect.

Conclusion

The establishment and maturation of the CFSpCC is the practical expression of NATO’s decision to treat space as a decisive theatre of operations. It is no longer a background service; it is the foundational layer upon which all modern MDO are built. By establishing space C2, bolstering operational support to MDO, and delivering robust awareness of the space domain, the CFSpCC underwrites the Alliance’s ability to fight and win in a contested environment.

This journey from coordination to command is sustained by the rigorous discipline of the METL and the strategic roadmap of campaign-focused plans. These tools ensure that our progress is measurable and our requirements are clear. However, the mission is not

yet complete. To fully operationalise the domain, the Alliance must continue to prioritise agile commercial integration, develop permanent force structures, and advance policy frameworks that allow information to flow at the speed of relevance.

Credible deterrence means that the Alliance must fight through the contested Space Domain and deliver joint effects at scale.⁷ The NATO space enterprise is steadily turning strategic aspiration into operational reality. The high ground may be contested, but through the CFSpCC, the Alliance has signalled its clear intent: it will be neither neglected nor ceded. ●

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Air Power at the Edge – Securing NATO’s New Frontiers

Introducing our JAPCC Annual Theme

By Colonel Kevin ‘Tread’ Anderson, US Air Force, Chief of Staff, JAPCC

Aircrew aboard the HMS Prince of Wales participate in Exercise Steadfast Defender in the High North.

Introduction

We are proud of the incredible work the JAPCC has accomplished over the last year. In 2025, our research and analysis remained focused on the conflict in Ukraine and NATO’s collective defence in Eastern Europe. This focus is driven by the significant risks of large-scale conflict at the border. Our support for these efforts is essential and will continue as long as necessary. However, as the Alliance addresses the fires burning to the east, our Centre of Excellence must also look past the smoke, ensuring that our attention to our near borders does not blind us to the embers smouldering elsewhere.

To that end, at JAPCC we are shifting from a reactive scan across the border to a proactive scan of emerging threats on the horizon. We see this in the Arctic, for instance, where receding ice opens new avenues for strategic competition. We also observe this along key trade routes from the Red Sea to the Indo-Pacific,

where freedom of navigation is being challenged. Above us, the space domain is growing increasingly contested. Consequently, for the first time in our history, we have established an Annual Theme to guide our research and discussions: **Air Power at the Edge: Securing NATO’s New Frontiers.**

This theme explores the physical and conceptual boundaries of air and space power employment. The ‘Edge’ is not simply a reference to front lines. It includes the geographic edge, extending our operational reach into the High North and Indo-Pacific; the vertical edge, surpassing traditional altitude boundaries into near-space; the cognitive edge, where, despite the rise of artificial intelligence (AI), the human mind remains our ultimate asymmetric advantage; and it is the digital and logistical edge, where we must shoot, move, and communicate in austere environments where our supply chains are contested. This year, we will assess how NATO operates at these limits and advances into new frontiers.



NATO Secretary General Mark Rutte and Japanese Prime Minister Shigeru Ishiba reaffirm the vital link between Euro-Atlantic and Indo-Pacific security.

The Geographic Frontier

Our first step is to challenge our mental maps, beginning in the Arctic. For too long, we have accepted an artificial divide: a 'North American Arctic' secured by North American Aerospace Defense Command (NORAD), and a 'European High North' defended by NATO. While the environmental characteristics of these subregions differ, we plan to address the potential vulnerabilities created by this operational split, which creates a 'seam' in command authorities, data sharing, and situational awareness. This year, the JAPCC will explore how to close that seam and move towards a unified, trans-polar defence architecture. Our goal is to allow air power and information to flow without friction.

Simultaneously, we will turn our eyes toward the Indo-Pacific. This region is outside our traditional treaty area, but recent NATO summits underscore a fundamental truth: the security of the Euro-Atlantic and Indo-Pacific is increasingly interconnected. In this theatre, the Edge refers to the tyranny of distance. The Indo-Pacific therefore offers us lessons of scale, such as how to move, disperse, sustain, and protect forces across vast distances. It also demonstrates the application of Agile Combat Employment (ACE) across island chains versus the European continent, and the logistics networks needed for austere locations. Most importantly, we will consider how stronger Indo-Pacific partnerships can reinforce deterrence, uphold shared norms, and safeguard the global commons.

The Vertical Frontier

Currently, the Alliance operates in two main altitude bands: traditional air power (up to about 20 km) and space power (above the 100 km Kármán line). We think there is a strategic 'seam' in between those levels. The near-space domain is emerging as a frontier for hypersonics, high-altitude platform systems (HAPS), and very low Earth orbit (VLEO) technologies. This region offers opportunities for surveillance and rapid strike, but it also creates strategic ambiguity. It is too high for air traffic regulations and too low for current space treaties, creating potential blind spots in both sensor coverage and international governance. As activity in this zone increases, NATO must address this vertical gap before competitors do.

The Digital and Energy Frontiers

Beyond geography and orbits, we must also address the Digital Frontier. Future conflicts will require robust data processing at the tactical edge instead of relying on centralised headquarters. This shift to 'Edge Computing' is key to maintaining decision superiority in contested and degraded environments.

We must also consider the Energy Frontier. Edge data processing and projecting air power over long distances strains logistics if we rely solely on traditional fuels. Alternatives such as modular micro-reactors and



German Tornado fighters line the tarmac at Eielson AFB, Alaska, during the Pacific Skies deployment. By projecting air power from Europe into the North American Arctic, the Luftwaffe helps dissolve the artificial divide between NATO and NORAD defensive architectures.

synthetic fuels may help. Ultimately, without resilient power and rapid infrastructure, our advanced platforms cannot be sustained.

The Cognitive Frontier

This year, we will also examine the Cognitive Frontier. Despite advances in AI and autonomous warfare, war remains a human endeavour. As the tempo of combat accelerates, decisions will occur at machine speed and personnel will face greater pressure. We will explore how we train for uncertainty, build resilience against cognitive warfare, and optimise decision-making under extreme stress. While we develop sixth-generation fighters, we must also ensure we are preparing sixth-generation minds. Securing the cognitive

frontier requires investment in our military culture, exercises, and readiness to ensure our people remain our greatest advantage.

We look forward to a year of bold ideas. In 2026, you will find thought-provoking research on our website and in this journal, addressing these topics in depth. This theme will build toward our flagship event, the 2026 Joint Air and Space Power Conference, which will bring together leading experts to discuss Air Power at the Edge.

We cannot explore these frontiers alone. If you have relevant expertise or think we have overlooked an important area, we want to hear from you. Visit japcc.org and join the conversation. The world is changing fast, and the Alliance needs your perspective. ●



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An MDO Approach to NATO's Counter-IADS Strategy

Integrating Suppression of Enemy Air Defences and Cyber-Electromagnetic Activities

Lieutenant Colonel Athanasios Sdrakas, Hellenic Air Force, JAPCC

Introduction

Russia's war in Ukraine has shattered long-held assumptions about the ease of achieving air superiority. The conflict has demonstrated that even modern air forces struggle to dominate contested skies when faced with a dense, multilayered defence.¹ While much attention has been paid to the proliferation of unmanned aerial systems (UAS), the more enduring lesson for NATO is the resurgence of the Integrated Air Defence System (IADS). These systems now anchor adversary Anti-Access/Area

Denial (A2/AD) strategies, posing a direct challenge to how air power is projected and sustained.²

NATO's ability to deter and defend against a modern, IADS-equipped adversary requires a multi-domain campaign of suppression that is continuous, adaptive, and resilient. Future suppression of enemy air defences (SEAD) missions cannot rely solely on the traditional air-domain-centric model of airborne SEAD platforms – such as dedicated electronic attack aircraft, Wild Weasel units, and 5th-generation strike



fighters operating primarily against individual surface-to-air threats. It must evolve to utilise all assets and effects capable of neutralising a sophisticated IADS.³ Persistent electronic attack (EA), cross-domain cyber operations (CO), and precision kinetic effects must be orchestrated to create and exploit windows of opportunity at scale. NATO should therefore develop a framework that enables these effects to be sustained. Developing a framework to do so is central to sustaining NATO's deterrence posture, freedom of action, and credibility in collective defence.⁴

This begins with the integration of air-delivered SEAD effects and Cyber-Electromagnetic Activities (CEMA). Far from being a mere mix of jamming and

hacking techniques, CEMA provides an operational framework that treats cyberspace and the electromagnetic spectrum (EMS) as a unified manoeuvre space. Within this framework, electronic warfare (EW) and cyber capabilities converge to influence an adversary's Integrated Air Defence System (IADS) by manipulating the EMS, cyber terrain, and information environment.

'Integrating SEAD and CEMA is more than a procedural improvement; it changes how NATO defeats a modern IADS.'

Like traditional airborne SEAD, CEMA employs electronic attack techniques such as jamming, deception, and spoofing, but extends further to include cyber operations that penetrate radar software, command-and-control (C2) infrastructure, and air-defence networks.⁵ True integration must go beyond coordination: it requires an offensive counter-air 'system-of-systems' approach in which CEMA operators are fully embedded in mission planning and execution alongside airborne SEAD specialists. When electromagnetic attack, deception, cyber intrusion, and kinetic fires are synchronised in time and purpose, NATO can generate the unified effects needed to suppress or neutralise a modern IADS.⁶ This SEAD-CEMA coupling forms the foundation of a multi-domain strategy that achieves air superiority through the synergistic application of kinetic and non-kinetic effects across the EMS.⁷

The Operational Need for SEAD-CEMA Integration

Advanced air defence systems with sophisticated mobility, redundancy, and electronic countermeasures (ECM) can degrade the effectiveness of traditional air-employed SEAD.⁸ Russia's IADS illustrate how a multi-layered defence architecture can quickly detect, track, and neutralise traditional aerial threats in a congested environment. The SA-21 Growler



An EA-18G Growler with AN/ALQ-99 pods on the deck of the USS Abraham Lincoln.

(S-400) and S-500 Prometheus can target aircraft, missiles, and satellites. Mobile systems like the Buk-M2 (SA-17) and Tor-M1/M2 (SA-15), together with powerful EW platforms like the Krasukha-4, Divnomorye, and Murmansk-BN, support these kinetic effects by disrupting, deceiving, and degrading adversary sensors. Their effectiveness is amplified through Russia's sensor-fusion and battle-management networks, Baikal-1M, Polyana-D4M1, Nebo-M, which provide shared tracking data and coordinated engagements.⁹ When fully integrated, such an advanced IADS presents a high risk to traditional SEAD platforms unless they are supported by synchronised multi-domain effects, including cyber, space, and electromagnetic activities.¹⁰ Without synchronised lethal and non-lethal effects to achieve a level of suppression against a modern IADS, creating even limited pockets of air superiority is nearly unachievable.

An Effects-Based Framework: Lethal vs Non-Lethal SEAD and the Role of CEMA

SEAD uses various means to produce both lethal and non-lethal effects that degrade, deceive, deny, disable, or disrupt adversary IADS, as shown in Table 1.¹¹

Non-lethal SEAD effects, like those achieved with airborne electronic attack (AEA), rely on EMS jamming to defeat surveillance and fire control radars, and disrupt communications. Lethal SEAD effects use physical force or energy transfer, often via traditional kinetic weapons like anti-radiation missile (ARM) and precision strike weapons. In the future, emerging technologies, most notably directed energy weapons (DEWs), including high-energy lasers and high-power microwaves, could further expand the lethal effects arsenal.

CEMA offers a range of non-lethal effects, providing time-limited and reversible means to suppress adversary air defences. Traditional SEAD methods, such as employing ARMs and supporting EA, remain fundamental in disrupting IADS. However, the increasing complexity and resilience of modern IADS demand that these methods evolve. To remain effective, SEAD must incorporate the full spectrum of CEMA, which blends kinetic, electronic, and cyber capabilities into a unified operational concept. Integration of CEMA capabilities and effects from the earliest stages of operational design and campaign planning processes, co-locating cyber/EW planners within air tasking cycles, and synchronising target development, effects sequencing, and battle damage assessment across all domains rather than treating them as parallel or supporting activities.¹²

Category	Means	Description
Physical Destruction (Hard Kill)	Anti-Radiation Missiles (ARM)	Missiles that home in on radar emissions to destroy radar sites.
	Precision-Guided Munitions (PGMs)	Highly accurate bombs / missiles are used to strike IADS components.
	Directed Energy Weapons (DEW)	Lasers or high-energy beams are used to damage or destroy electronic systems.
	High-Power Microwaves (HPM)	Emits powerful microwave bursts to disable enemy electronics.
	Kinetic Strikes	Physical attacks on radars, SAM batteries, or C2 facilities.
	Special Operations Forces (SOF)	Covert missions to disrupt or sabotage IADS infrastructure.
	Support Jamming (SJ)	Jamming that degrades enemy radar and communications.
Sensor Denial (Soft Kill – EW)	Escort Jamming (EJ)	Jamming support from aircraft accompanying strike packages.
	Stand-In / Stand-Off Jamming	Jamming is conducted from near-target or distant positions.
	Digital Radio Frequency Memory Jamming	Generates coherent false signals.
	Radar Spoofing / Deception	Manipulates radars to display false tracks or ghost formations.
	GPS / PNT Denial	Denies accurate navigation / timing cueing to disrupt engagements.
Logic / Network Disruption (Cyber)	Cyber Intrusion into IADS	Gains access to modify, disable, or corrupt radar / C2 logic.
	Data Injection / Manipulation	Alter sensor feeds, track tables, or identification databases.
	Admin / Authentication Lockout	Blocks operator access or inhibits system configuration.
	C2 Node Disruption	Cyber effects degrade routing, fibre-optic networks, or SATCOM.
	Malware Targeting Sensor Firmware	Corrupts radar modes, ECCM routines, timing or processing algorithms.

Table 1: SEAD effects and CEMA contributions across lethal and non-lethal means.

Accordingly, CEMA effects must be integrated from the earliest stages of operational design and campaign planning. This includes embedding cyber and EW planners within air tasking processes and synchronising target development, effects sequencing, and battle damage assessment across all domains. Such convergence underpins the future of SEAD: a cross-domain, layered approach that synchronises kinetic fires, EW, and cyber warfare (CW). Through SEAD-CEMA

integration, NATO can generate decisive effects within contested electromagnetic environments, disrupting enemy air defences through destruction, deception, denial, and digital exploitation.

To illustrate how these dynamics unfold in real operations, the following case studies examine SEAD-CEMA integration across permissive, contested, and advanced IADS environments.



F-35 Lightning II aircraft flying in close formation. The F35 is ideal for stand-in SEAD asset in contested airspace.

Case Study 1: Operation Unified Protector (Libya, 2011) – SEAD in a Permissive Environment

NATO's intervention in Libya successfully enforced a no-fly zone and neutralised most of Libya's antiquated IADS. The rapid degradation of Libyan air defences, however, masked significant structural weaknesses in NATO's SEAD posture.

- **Doctrine–Reality Gap.** Existing Cold War-era SEAD doctrine was ill-suited to the decentralised and mobile Libyan defences. NATO lacked a doctrinal framework for dynamic SEAD in a fluid operational environment.¹³
- **Over-Reliance on US Enablers.** SEAD support to the Alliance depended almost entirely on US Navy EA-18G Growlers and US Air Force F-16CM Wild Weasels, supported by US Air Force intelligence, surveillance, and reconnaissance (ISR) assets (e.g. E-3 AWACS, E-8 JSTARS), aerial refuelling, and precision strike capabilities.¹⁴
- **Interoperability and C2 Challenges.** The transition from the US Secret network (SIPRNET – Odyssey Dawn) to the NATO Secret Wide Area Network (NSWAN – Unified Protector) resulted in delays and data loss, and Battlefield Information Collection and Exploitation Systems (BICES) was not fully integrated with US Africa Command AFRICOM. This was more than a C2 friction point: if NATO struggled to share basic targeting data in 2011, it would not be able to exchange far more

complex cyber intelligence, EW mission libraries, or EMS threat files in a future SEAD-CEMA campaign. In Libya, we learned an important lesson: if the network is fragmented, CEMA is impossible.¹⁵

Assessment: Unified Protector's permissive conditions masked the Alliance's lack of indigenous European SEAD/Destruction of Enemy Air Defences (DEAD) capacity. The operation underscored the need for NATO to develop a joint, multi-domain SEAD doctrine that fuses EA, cyber, and ISR into a combined planning and execution framework.¹⁶

Case Study 2: The Ukrainian Crucible (2022–Present) – Attritional SEAD in a Contested Environment

The Russian invasion of Ukraine provided the first real assessment of SEAD against a modern and adaptive IADS. With no formal NATO involvement and few trained SEAD air operators, Ukraine relied on an attritional, multi-domain suppression, providing rare insight into degrading Russian IADS.

- **Innovative Tactics & Centrality of UAS.** Ukraine relied heavily on small military and commercial drones to identify Russian SAMs, radars, and EW units, enabling a simple but effective targeting cycle that quickly paired 'finders' (UAS) with 'shooters', such as artillery, missiles, and one-way attack OWA drones.¹⁷



Integrated cyber and electromagnetic activities (CEMA), showing how cyber intrusion, jamming, and precision strike effects combine to suppress modern IADS.

- **Multi-Domain Synergy: ISR-Enabled Precision Fires Against IADS.** ISR data from drones has been linked to precision fires from high mobility artillery rocket system (HIMARS), M270 guided multiple launch rocket system (GMLRS), and OWA drones, systematically degrading Russian IADS over time, including confirmed strikes on S-400 radars and launchers. This represents a genuine multi-domain SEAD construct, where air/space ISR enable land-based fires to suppress threats to the air domain.¹⁸
- **SEAD & CEMA Integration.** Ukraine rapidly improvised methods of suppression that blended kinetic, EW, and cyber effects. Pilots adopted 'Wild Weasel-style' tactics, exposing themselves to radar emissions to provoke Russian engagement and enable strikes with Western-supplied AGM-88 HARMs adapted for MiG-29 and Su-27 aircraft. The latter 'FrankenSAM' hybrids – Western missiles on Soviet launchers – demonstrated a high degree of battle-field innovation. However, these strikes alone could not permanently suppress a Russian IADS that remained mobile, resilient, and shielded by EW assets such as Krasukha-4 and Leer-3.¹⁹
- **The Virtual Dimension.** The KA-SAT/Viasat attack in February 2022 was not just a communications disruption; it was a counter-C2 strike that

temporarily blinded parts of Ukraine's command network during the invasion's opening phase. Ukrainian CO targeted logistics and navigation networks, while tactical jamming, spoofing, and GPS denial created temporary windows that allowed drones and missiles to penetrate.²⁰ The conflict has thus evolved into a continuous fight for EMS dominance, with both sides employing increasingly low-cost CEMA tools.²¹

Assessment: Ukraine's attritional SEAD highlights the need for continuous, multi-domain suppression, rather than episodic strikes, utilising ISR, precision fires, cyber, and EW to degrade IADS steadily. The conflict also reveals the rise of democratised or 'guerrilla' CEMA, where inexpensive commercial tools – such as Software-Defined Radio (SDRs), open-source software, and improvised jammers – deliver real operational effects.

Case Study 3: Israel-Iran War (June 2025) – Advanced SEAD-CEMA Integration

Israel's networked integration of cyber, EW, and precision strikes demonstrated that sophisticated multi-domain effects can achieve strategic dominance with



The S-400 Triumf Russian air defence SAM/Transporter Erector Launcher (TEL).

relatively few assets. In contrast, Iran's reliance on mass-saturation tactics consumed vast quantities of munitions without achieving decisive results, illustrating that sheer volume cannot compensate for a lack of cross-domain coordination.²²

- **CW–EW Opening Moves.** Pre-emptive CO reportedly degraded Iranian radar networks, satellite communications, and C2 nodes in the first hours, creating short windows for Israel Air Force (IAF) strike packages to enter contested airspace with reduced risk.²³ A Mossad-linked mission to sabotage fibre-optic lines and disrupt radar facilities inside Iran compounded the cyber effects, physically degrading Iranian network resilience.

- **IADS Resilience & Temporary Kinetic Windows.** Even after early blows, Iran dispersed and reconstituted air defence coverage within 24–48 hours, relocating its Khordad-15 and Raad SAM systems and command elements. This limited opportunities for HARM employment, forcing Israel to rely on persistent ISR and dynamic re-attack windows with UAVs.²⁴ Coordinated cyber actions and GPS jamming degraded air defence capabilities and enabled windows for kinetic missions to succeed.²⁵

- **Massing Multi-Domain Effects.** Iran launched mixed salvos of ballistic missiles and Shahed drones,

aiming to saturate Israel's layered defences. Although most were intercepted, the volume of fires forced the IAF to shift its efforts towards defending key military targets. This created a trade-off: every asset pulled into missile defence was an asset unavailable for SEAD tasks.²⁶ Israel countered with its own waves of UAVs, loitering munitions, and decoys to overload Iranian engagement zones, enabling F-35I Adir aircraft to strike Bavar-373 and S-300 sites protecting Natanz and Fordow. The use of inexpensive decoys to drain SAM magazines mirrors Russian concepts, as seen with Geran/Shahed drones.²⁷

- **Layered Multi-Source Intelligence.** The use of national intelligence, satellite imagery, and open-source intelligence (OSINT) rapidly revealed movements on both sides. Both sides faced unprecedented transparency.²⁸

Assessment: Iran proved relatively responsive following initial SEAD effects, but Israel maintained the advantage through synchronised cyber, EW, and kinetic actions that created recurring windows of vulnerability. Their persistent SEAD cycles – suppress, exploit, re-suppress – aided by both military intelligence and OSINT, ensured proactive suppression of adversary defences to enable other functional objectives (strike, ISR, pursuit of air superiority).

Recommendations

Operational Adjustments

- **Establish SEAD-CEMA planning cells.** NATO should form integrated SEAD-CEMA cells within Allied Air Command (AIRCOM) and especially at the Joint Force Command (JFC) level, integrating cyber, EW, ISR, and all components (air, land, maritime, and space), ensuring multi-domain planning and targeting. These cells must also begin developing detailed, 'on-the-shelf' SEAD-CEMA plans, since adequate cyber/EW preparation requires months or years of access, not last-minute tasking. The Alliance must address classification and releasability barriers that restrict multinational targeting and integration, delegate approval of non-strategic cyber effects to the JFAC Commander level to exploit fleeting SEAD windows. NATO should adopt a pre-approved library of generic cyber payloads for rapid deployment. CEMA must be fully integrated into the Joint Targeting Cycle and reflected in the ATO as a standard SEAD tool.

Capability Development and Investment

- **Build a layered, interoperable SEAD-CEMA capability portfolio.** NATO's Defence Planning Process should direct investment into both high-end, exquisite effectors and scalable attritable systems. This includes advanced ARMs, stand-in EW drones, survivable ISR platforms, long-range precision strike weapons, and affordable swarms of unmanned systems proven effective in Ukraine.
- **Enforce open architecture standards.** The Conference of National Armaments Directors (CNAD) should mandate that all new CEMA-related systems comply with open architecture and data standards. This could serve to break the cycle of proprietary, non-interoperable systems and ensure that future NATO assets are integrated by design.
- **Reduce over-reliance on US enablers.** Allies must develop and acquire EW, ISR, and SEAD assets to create a more balanced and sustainable defence capability.

Training, Exercises, and Professional Development

- **Evolve NATO training and exercises for MDO.** Flagship exercises (e.g., Ramstein Flag, Ramstein Guard) should stress SEAD-CEMA integration against an

adaptive and advanced adversary. Scenarios should include contested EMS, enemy cyber intrusions, and adaptive red IADS. Advanced live virtual constructive (LVC) environments should be expanded to realistically simulate peer-level opposition.

- **Create a cadre of multi-domain practitioners.** NATO and its member states should establish and/or enhance recognised career paths for CEMA professionals. This includes expanding specialist training (e.g., Non-Kinetic Effects Coordination courses) and operational continuation training to provide qualified and proficient operators for SEAD-CEMA cells.
- **Educate commanders.** Senior leaders must be prepared to understand CEMA effects, assess non-kinetic risks, and confidently integrate capabilities into operations. This reduces cultural bias toward familiar kinetic tools and promotes genuinely multi-domain decision-making.

Doctrinal Development

- **Codify SEAD-CEMA within MDO.** NATO should formally embed SEAD-CEMA integration within its MDO doctrine. This doctrine must define authorities, command relationships, targeting processes, and escalation thresholds for integrated cyber, EW, and kinetic suppression. It will provide a common Alliance-wide framework, ensuring that CEMA is not treated as an adjunct but as an indispensable pillar of future SEAD campaigns.

Future Outlook

Integrating SEAD and CEMA is more than a procedural improvement; it changes how NATO defeats a modern IADS. The aim is not only to disrupt radars or individual sensors, but to pressure the adversary's entire decision-making chain – its data links, software logic, and C2 nodes. When CO, EW effects, and precision fires are synchronised, they create dilemmas the defender cannot resolve quickly, preserving NATO's freedom of action and supporting air superiority in contested environments.

Looking ahead, SEAD-CEMA will sit at the core of NATO's MDO model. Future IADS will be too mobile, networked, and software-driven for traditional SEAD to be effective alone. NATO will need earlier

cyber shaping, stand-in EW capabilities, resilient ISR, and integrated targeting processes that align effects across all domains. Embedding SEAD-CEMA teams into campaign design will help ensure the Alliance can challenge advanced IADS, maintain deterrence, and retain the initiative in future high-end conflicts.²⁹ ●

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Countering Russia's Glide Bomb Warfare in Ukraine

Observations and Lessons for NATO on Neutralising Long-Range Weapons

By Lieutenant Colonel Giovanni Zanier, ITA Air Force, JAPCC

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Introduction

The Russia-Ukraine war has served as a proving ground for military innovation on both sides of the conflict. While Ukrainian forces pioneered small, unmanned aircraft systems (UAS) technology to stall ground assaults, Russia's most effective adaptation has been the mass deployment of glide bombs, which have helped

Moscow translate small tactical gains into significant strategic challenges for Ukraine. Glide bombs have become a transformative element in the conflict.

A glide bomb is an aerial munition that utilises aerodynamic surfaces, such as wings and control fins, to achieve a significantly greater standoff range than a traditional unguided bomb. Upon release, deployable

wings open allowing the munition to enter a controlled glide that converts altitude and airspeed into horizontal distance. Guidance systems, typically a combination of satellite navigation (GPS or GLONASS) and inertial navigation systems (INS), directs the weapon towards its target while the releasing aircraft turns away from the threat.¹

This article contends that glide bombs have had a greater battlefield impact than almost any other Russian weapon system due to a confluence of factors: they are cost-effective, particularly when using conversion kits on existing stockpiles of unguided bombs; they deliver substantial payloads; they are sufficiently accurate for many tactical purposes; and critically, they allow launch aircraft to remain at stand-off distances, thereby reducing risk from Ukrainian air defences.² The tactical, strategic, and psychological impacts of these weapons have been profound. Russia's employment of these weapons was a significant factor for Ukraine on the Zaporizhzhia front in the summer of 2023, contributed to the fall of Avdiivka in early 2024, and has been

a key element applying pressure in battles like Chasiv Yar, a strategic high ground west of Bakhmut, and many other instances throughout the year.^{3,4,5,6}

However, Ukraine's improving countermeasures reveal the strengths and limitations of the weapon system, presenting valuable lessons to NATO for the use of, and defence against, glide bombs in future conflicts.

Glide Bomb Overview

Glide bombs fall into two categories: traditional bomb bodies fitted with conversion kits, and purpose-built munitions. Conversion kits are add-on packages that modify existing unguided bombs. Notable examples include the US Joint Direct Attack Munition-Extended Range (JDAM-ER) and Russia's Unified Gliding and Correction Module (UMPK). Purpose-built glide bombs, including the US's GBU-39 Small Diameter Bomb (SDB) and Russia's newer Universal Interspecific Glide Munition (UMPB), are designed as integrated glide weapons.



GBU-39 Small Diameter Bombs under an A-10 Thunderbolt II.

Both types offer the key advantage of increased stand-off range, enabled by aerodynamic surfaces that allow the weapon to glide rather than follow a simple ballistic trajectory. This permits delivery platforms, usually fighters or bombers, to release weapons from outside the ranges of enemy air defences. Ranges vary significantly based on launch altitude and speed, from tens of kilometres to over 100 kilometres for some systems.⁷ Payloads are scalable for conversion kits (for example,



UMPB D-30SN, Russian purpose-built glide bomb.

250 kg, 500 kg, 1,500 kg, or even 3,000 kg class bombs) or fixed according to the purpose-designed warhead.⁸

Today, glide bombs like the JDAM-ER and SDB are common among NATO arsenals, with several other variants in development. For Russia, two specific weapons currently make up most of its inventory.⁹

Russian Glide Bombs: UMPK and UMPB

Russia's glide bomb arsenal primarily comprises the UMPK kit and the UMPB munition. The UMPK is an inexpensive conversion kit estimated at around \$ 20,000. It is designed to be strapped onto Soviet-era FAB-series bombs, such as the FAB-500 and FAB-1500, allowing Russia to convert its vast stockpiles of unguided munitions into glide bombs. While cost-effective, early UMPK versions had a crude construction and relied on

civilian-grade electronics, exposing production to supply chain vulnerabilities.

Russia seemingly recognised these shortcomings and subsequently manufactured the UMPB D-30SN, a purpose-built glide bomb. It integrates the warhead (reportedly based on the FAB-250) and guidance systems into a more aerodynamically refined package. First observed in Spring 2024, the UMPB is assessed to offer



FAB-1500-UMPK 'The Russian JDAM'

improved ranges, potentially up to 90 km compared to the UMPK's typical 60–70 km, and may include enhanced resistance to electronic warfare (EW).¹⁰

Employment in Ukraine and its Consequences

Early in the war, initial glide bomb expenditure was limited. However, this escalated markedly so that by early 2025 Russia was releasing approximately 3,500 UMPK-equipped bombs per month, or over 100 per day across the front. These weapons have been predominantly used against static targets, overwhelming defences and degrading Ukrainian positions ahead of ground assaults. Russian strikes were particularly concentrated along the eastern and southern front lines and, increasingly, against urban centres like Kharkiv and Sumy.

Feature	UMPK (FAB-500 based)	UMPB D-30SN	JDAM-ER (Mk82/83/84 based)	SDB (GBU-39/B)
Est. Unit Cost	Low (~\$25k kit + bomb) ¹¹	Moderate (Likely >UMPK)	Low-Moderate (~\$30k+ total) ¹²	Moderate (~\$40k+)
Typical Range	Medium (60–70 km) ¹³	High (Est. ~90 km) ¹⁴	Medium (~70+ km) ¹⁵	High (111+ km) ¹⁶
Guidance	GNSS/INS ¹⁷	GNSS/INS ¹⁸	GNSS/INS ¹⁹	GNSS/INS ²⁰
Typical Payload	~150–200 kg HE (FAB-500) ²¹	~100 kg HE ²²	~90 kg HE (Mk82) ~200 kg HE (Mk83) ~430 kg HE (Mk84)	~93 kg HE ²³
Accuracy (CEP)	Good (Optimal: 8–15 m ²⁴), Poor (Degraded/EW) ¹²	Likely Good (>UMPK)	Very Good	Very Good

Table 1: Comparative Overview of Selected Glide Bombs.

Russian forces primarily utilise Su-34 ‘Fullback’ fighter-bombers as launch platforms, often carrying four glide bombs per sortie. Su-30SM and Su-35 ‘Flanker-E’ aircraft also employ these weapons.¹² These aircraft typically release weapons 35–50 km from the front line, though ranges can extend further with high-altitude launches. While greater stand-off ranges are aerodynamically possible, increased release ranges are likely to enlarge miss distances and complicate targeting.

Operationally, these weapons have enabled Russian forces to achieve tactical successes by providing a means to deliver heavy ordnance from relative safety. In urban warfare scenarios such as Kharkiv, glide bombs have reduced buildings to rubble, denied cover to defenders, and produced substantial psychological effects.^{25,26}

This mass employment strategy aims to achieve attrition and create breaches in Ukrainian lines that ground forces can then exploit.²⁷ The systematic destruction of Ukrainian fortifications was a key factor in the Russian capture of Avdiivka and has been instrumental in applying pressure in battles like Chasiv Yar. Glide bombs have also been used to interdict tactical resupply routes and target-hardened command posts and infrastructure.

Limitations and Ukrainian Countertactics

Despite their effectiveness, Russian glide bombs have important limitations. Most notably, they are dependent upon Global Navigation Satellite System (GNSS) signals, especially GLONASS, rendering them susceptible to EW. Reports suggest that when GNSS is disrupted, the UMPK’s backup INS is prone to significant inertial drift over the weapon’s flight time, causing it to veer off course in the absence of a stable GNSS signal. Several conversion kit-equipped UMPK have been found on both sides of the battlefield, likely the result of weapons malfunctions or guidance errors that produced large miss distances.²⁸

Furthermore, despite the inherent stand-off ranges afforded by glide bombs, the Su-34s and Su-35s can, and have, been targeted by long-range air defence systems and fighter aircraft. Tactics on both sides have evolved quickly, as have operator proficiency levels, creating a hazardous environment for fighters delivering glide bombs and for those attempting to intercept the bomb droppers.²⁹

Ukraine is actively exploiting such vulnerabilities and evolving tactics to mitigate the glide bomb threat. Electronic warfare has emerged as the most effective



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FAB-3000 with an UMPK kit deployed in the air.

countermeasure to glide bomb employment. The Pokrova system and other specialised jammers have reportedly been effective in degrading UMPK accuracy, while the widespread Ukrainian use of dispersion and concealment has complicated Russian efforts to obtain timely and accurate target coordinates. These factors appear to be steadily reducing the effectiveness of Russian glide bomb employment, leading some Russian military bloggers to lament the effectiveness of Ukrainian countermeasures.³⁰

Despite these Russian vulnerabilities, the sheer volume of glide bombs presents a formidable defensive challenge for Ukraine. Short-range air defence systems (SHORAD), man-portable air defence systems (MANPADS), and anti-aircraft guns generally lack the range to engage bombs launched from typical stand-off distances. Advanced systems such as the NASAMS, Patriot, and S-300 could theoretically intercept glide bombs, but their continuous use is unsustainable owing to war-reserve material (WRM) and cost limitations.

Russia's glide bombs create a significant asymmetric advantage. To address the challenge of costly intercepts, Ukraine will need to continue adapting toward more proactive and innovative measures. Countermeasures are likely to expand in non-kinetic capabilities such as

EW techniques and AI-enabled detection methods. One promising approach is to 'attack the archers' by directly targeting launch platforms in the air or on the ground. Ukraine might adopt a more aggressive strategy with its F-16s to challenge airborne Russian bombers at greater distances, though this carries significant risk given formidable Russian air defences. Alternatively, attacking the 'archers' on the ground may present lower risk. The major drone attack on Russian strategic bombers in June 2025, for example, suggests that ground attacks will remain a significant vulnerability for glide bomb delivery platforms.^{31,32}



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FAB-500T with a UMPK kit under the wing of a Su-34.

NATO Implications: Disrupting the Kill Chain

For NATO, the biggest concern with glide bombs and other inexpensive munitions is the cost-imposition dilemma. Massed quantities of relatively inexpensive stand-off weapons can saturate and overwhelm sophisticated, high-cost defences. This challenge is magnified by the likelihood that such systems will proliferate widely.

To counter this, NATO should adapt by seeking ways to disrupt glide bombs across the entire targeting cycle. This holistic approach prioritises proactive and cost-effective measures at every stage in the kill chain rather than focusing primarily on expensive terminal defence.

1. Deny the Target

The first line of defence is to prevent the adversary from effectively targeting Alliance forces. The Agile Combat Employment (ACE) concept, which emphasizes dispersal, unpredictability and movement, is critical to future survivability across all services. ACE must be coupled with robust camouflage, concealment, and deception (CC&D) measures that pair traditional camouflaging and concealment methods with modern multi-domain information and psychological operations to disrupt the find, fix, target (F2T) process.

2. Disrupt the Weapon

NATO must invest in advanced, adaptable EW systems capable of countering current and future adversary GNSS signals, degrading guidance systems and creating large miss distances. As a final layer against the munition, the Alliance needs a greater capacity of cost-effective kinetic defence options. This includes moving beyond high-end systems such as Patriot and NASAMS and investing in advanced terminal gun systems, drone interceptors, and directed-energy weapons.

3. Destroy the Shooter

The most decisive way to defeat glide bombs is to destroy the launch platform before weapon release. 'Killing the archers' remains a foundational approach,

but it requires robust capabilities for Suppression/Destruction of Enemy Air Defences (SEAD/DEAD) to allow friendly air power to operate in hostile territory and target launch platforms.³³ Achieving this requires continued investment in long-range air-to-air missiles, advanced fighter aircraft, and deep strike assets capable of holding adversary aircraft and airfields at risk.³⁴

Conclusion

Russia's widespread use of glide bombs in Ukraine has reshaped the modern battlefield, demonstrating that simple, cost-effective stand-off weapons can achieve strategic effects when employed at scale. By converting legacy munitions into stand-off weapons, Russia has created a persistent and scalable threat that imposes a severe cost-imposition dilemma upon even the most advanced air defence systems. This is not a temporary battlefield adaptation, but a feature of future conflict that NATO must confront.

'Russia's widespread use of glide bombs in Ukraine has reshaped the modern battlefield, demonstrating that simple, cost-effective stand-off weapons can achieve strategic effects when employed at scale.'

For the Alliance, defending against this threat requires a robust, layered approach designed to disrupt enemy targeting, defeat the munition and destroy its delivery platform. This demands investment in scalable countermeasures, including expansive CC&D, advanced EW and low-cost kinetic interceptors. Critically, it reinforces the necessity of fielding a credible and resilient counter-air capability. The skies over Ukraine have delivered a timely reminder that in an era of standoff weapons, the ability to contest and control the air remains the fundamental prerequisite for success on the modern battlefield. ●

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Next-Generation Software Defined Radios

Forging the Digital Backbone of the Modern Battlespace

By Petty Officer 2nd Class Chris Parsons, Royal Canadian Navy

M Hands, Digital Screen: © SWKStock/Shutterstock.com; Soldiers: © charnsitr/Shutterstock.com; Fighter Jets: © Faizinraz/Shutterstock.com; Satellites: © Dima Zel/Shutterstock.com; Navy Ships: © wz94/Shutterstock.com; Digital Horizon: © Iryna Dincer/Shutterstock.com

Human-machine collaboration visualising multi-domain data to support faster, smarter operational decision-making.

Introduction

The modern battlespace is no longer confined to the traditional boundaries of Air, Land, or Sea domains. NATO now operates in an integrated battlespace where Space, Cyber, and the electromagnetic spectrum are equally contested. This environment demands a unity of effort that is unattainable without a robust, adaptive, and interoperable communications backbone. In this era, the centre of gravity has shifted from individual platforms to the networks that connect them. Success in multi-domain operations relies on the seamless flow of data, including its confidentiality, integrity, and availability.

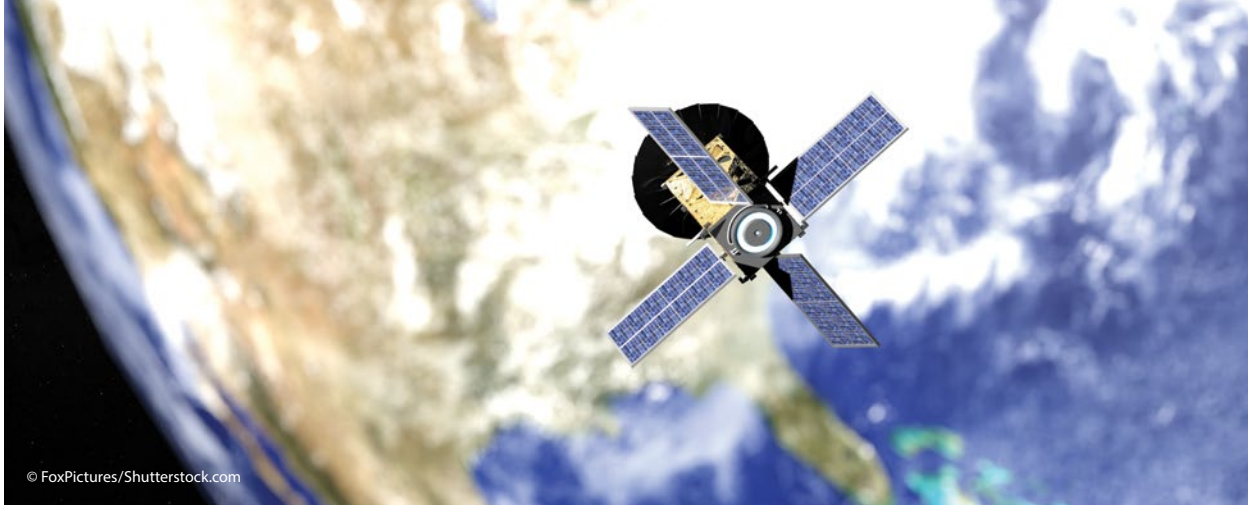
As one experienced operator recently observed, 'Multi-Tactical Datalink (TDL) is the bloodstream of multi-domain operations.' Tactical data is not a nicety; it is a strategic necessity. Situational awareness, coordinated fires, and combined defence hinge on assured access to timely, accurate information. NATO nevertheless

faces a critical challenge. Its current infrastructure, built on legacy systems and disparate national investments, struggles to keep pace. Maintaining existing TDLs such as Link 16 is no longer sufficient in the face of sophisticated electronic warfare and near-peer adversaries. The Alliance must therefore forge an interconnective digital backbone capable of spanning all domains and adapting to the battlefield in near real time.

The key to this transformation is the Software Defined Radio (SDR). By decoupling waveform capabilities from rigid hardware constraints, SDRs offer the agility, scalability, and interoperability required to bridge the gap between legacy fleets and next-generation networks.

From Link 11 to Link 22: Lessons from the Evolution of NATO TDLs

NATO's experience developing common tactical networks spans decades of both successes and setbacks.



A notional CubeSat in Low Earth Orbit (LEO), representative of small satellite platforms that increasingly leverage modular architectures and SDRs to enable flexible, reconfigurable communications.

The progression from Cold War-era Link 11 to the modern Link 22 illustrates how tactical networking has adapted to evolving operational demands.

Link 11 was innovative for its time. It allowed surface ships, aircraft, and command facilities to exchange digital tracks, delivering a previously unimaginable level of situational awareness. However, its polling topology, vulnerability to jamming, and limited data rates were significant drawbacks. Link 16 addressed these shortcomings by providing higher throughput, improved jamming resistance, and Time Division Multiple Access (TDMA). It became the foundation of Allied air warfare in conflicts such as the Balkans and Afghanistan.

Link 16, however, also has limitations. Its line-of-sight requirement creates coverage gaps over oceans and mountains, while reliance on dedicated terminals and fixed spectrum allocation limits scalability. Link 22 was developed to replace Link 11 and address these issues by providing beyond-line-of-sight connectivity for joint and maritime forces via HF and UHF bearers with modern cryptography. Widespread adoption, however, has been hampered by the cost and logistical complexity of retrofitting legacy platforms with dedicated hardware.

The lesson is clear. Each successive TDL generation is shaped by mission requirements but ultimately constrained by hardware.

As operational theatres expand and data demands grow, NATO can no longer sustain decade-long development cycles for waveform-specific radios and isolated systems. The shift toward SDRs represents the first major departure from this outdated approach.

SDRs: From Radios to Network Gateways

Unlike traditional radios tied to specific hardware and waveforms, SDRs shift core functionality into software. A single SDR can support multiple waveforms, be retuned in real time, and be updated throughout its operational life without costly hardware replacement.

This adaptability makes SDRs the universal interpreters of the battlespace. A single terminal can simultaneously support Link 16, national waveforms, and emerging data transfer capabilities. Software updates replace the need for hardware upgrades, enabling the rapid integration of new operational requirements. Most importantly, SDRs allow NATO commanders to dynamically reconfigure communications architectures by increasing throughput, switching frequencies to avoid jamming, or including coalition partners in mission-specific networks.

SDRs offer significant operational benefits. At sea, they reduce antenna clutter and terminal proliferation on already crowded vessels, increasing task group resilience. Air forces can change waveforms mid-mission, cooperate with coalition partners, or switch to low-probability-of-intercept communications in contested airspace. Land forces can use SDR-driven mesh networks to link units across line-of-sight gaps via unmanned aerial relays and satellite gateways.

In practice, SDRs transform radios from basic transceivers into intelligent network gateways. This allows the convergence of tactical links, strategic satellite communications (SATCOM), and commercial



Over 3,000 engineers and operators participated in CWIX25, NATO's premier digital interoperability event. 'Success depends on the seamless integration of Allied capabilities. CWIX delivers that interoperability', said NATO Supreme Allied Commander Transformation Adm. Pierre Vandier.

networks into a unified system capable of conducting multi-domain operations.

space assets is therefore a necessity for operating in a contested, multi-domain environment.

The Space and Commercial Dimension: Satellites as Tactical Enablers

No discussion of future NATO communications is complete without consideration of space and commercial operators. The rise of LEO constellations, such as OneWeb and Starlink, has revolutionised tactical networking. Where military SATCOM was once characterised by limited bandwidth and sparse coverage, LEO constellations provide unprecedented global coverage, redundancy, and bandwidth.

SDRs serve as the interface to this new environment. When configured with appropriate waveforms, they can employ commercial constellations as a secondary transport layer within the military data fabric. For example, a ground unit may employ Link 16 for local situational awareness while using LEO satellites for backhaul to higher headquarters. A naval task group may combine military SATCOM with commercial LEO to build resilience against jamming or interception.

Relying on non-military infrastructure during conflict introduces vulnerabilities but also provides resilience through redundancy. If one network fails, another can assume the load. Integrating SDRs with commercial

Operational Impact: From Case Studies to the Tactical Edge

Recent conflicts demonstrate that communications at the edge can be decisive. The war in Ukraine is a case in point. Ukrainian forces have effectively employed a combination of commercial SATCOM, mobile ad hoc networks, and tactical secure radios to outpace adversaries with less responsive systems. Linking sensors, shooters, and decision-makers in near real time has been critical.

This strategic lesson applies directly at the tactical edge. Consider a ground unit in remote terrain that is unable to contact brigade command because terrain interrupts line-of-sight communications. Without connectivity, situational awareness is lost. With an SDR-enabled mesh network, the unit can route communications through a UAV relay to maintain contact.

Maritime operations in extreme environments, such as the High North or the Baltic Sea, similarly depend on reliable connectivity. Weather and terrain frequently obstruct line-of-sight communications. SDR-enabled Link 22, augmented by HF, SATCOM, and UAV relays, enables seamless maritime situational awareness. For an individual destroyer, this changes operational realities. An un-networked ship is isolated,



Joint Terminal Attack Controllers (JTAC) train with Hand-Held Link 16 (HHL16) devices. Future versions, like the AN/PRC-161 BATS-D, will add SDR capabilities, providing BLOS, datalink-based secure comms, and improved battlespace awareness.

‘blind’ beyond its own sensors. With SDRs capable of simultaneous communications on Link 16, Link 22, and SATCOM, that same ship becomes a critical node in NATO’s Integrated Air and Missile Defence.

Air operations demonstrate similar requirements. In multinational exercises, coordinating dozens of aircraft from various nations is essential. A fighter without a data link is limited to its own radar. When networked into a coalition via SDRs, it can receive targeting data from an airborne early warning (AEW) aircraft, another Allied fighter, or a warship hundreds of kilometres away, extending its survivability and lethality.

Training and Exercises: Building Confidence in Connectivity

Technology alone does not ensure success. It must be tested, validated, and proven through rigorous exercises. NATO values interoperability exercises such as the Coalition Warrior Interoperability Exercise (CWIX), Bold Quest, and Steadfast Defender as proving grounds for SDR-based communications.

CWIX is a key test bed for experimenting with new waveforms, testing SDR configurations, and integrating national systems into the wider NATO network. It treats

interoperability as a continuous, iterative process, not a one-time certification.

Seaborne exercises such as Formidable Shield, and air-focused exercises such as Red Flag, demonstrate operational impact. Air, naval, and ground forces from member countries may arrive with different equipment, but depart as integrated, efficient units. This transformation is enabled by accurate SDR configuration. This is how training converts technical capability into the operational confidence on which commanders rely.

Challenges: Security, Governance, and the Human Dimension

While powerful, SDRs are not without challenges. Their programmability is both a strength and a potential vulnerability. Robust cryptography, secure waveform management, and layered cyber security are essential to prevent misuse. NATO must invest in both the radios themselves and the test, certification, and key management infrastructure that underpins them.

Policy challenges also remain. Allies must find ways to share waveforms, intellectual property, and cryptographic solutions without compromising national sovereignty.



Operations centres depend on resilient communications architectures to fuse distributed sensor and platform data into a common operational picture. In many modern constructs, SDRs and tactical data links provide the adaptable transport and standardised exchange mechanisms that make such integration possible.

NATO must also prevent the proliferation of national waveforms from creating new digital stovepipes. These governance issues are central to Alliance unity.

The human factor is equally important. Operators, maintainers, and Joint Interface Control Officers must be trained to exploit the flexibility that SDRs provide. Doctrine and operational concepts must keep pace with technology, or the radios will not be employed to their full potential. Developing personnel is as important as acquiring hardware.

Leadership Roadmap: Building NATO'S Digital Backbone

For NATO commanders, the message is simple. SDRs are more than radios; they are the enablers of the digital backbone for multi-domain operations. A vision-driven roadmap for 2025–2035 must include:

- **Standardisation:** mandate joint requirements across services and member nations to phase out legacy, single-purpose terminals.
- **Governance:** establish a NATO Waveform Library to allow secure sharing of approved waveforms across the Alliance.
- **Integration:** integrate commercial space and terrestrial 5G/LTE infrastructure based on a 'resilience-by-design' policy.
- **Doctrine:** update doctrine to recognise connectivity as a core mission function rather than a supporting capability.

- **Training:** invest heavily in simulation and training to ensure commanders and operators understand both the capabilities and the limitations of SDR-enabled networks.

This effort requires political and financial support. Communications programs are often secondary to major platforms such as fighters or frigates. Without connectivity, however, these platforms cannot realise their full operational potential. Leadership must recognise that robust communications are a force multiplier rather than a second-order afterthought. NATO's digital backbone will emerge only through deliberate design, investment, and security planning.

Forward-Looking Vision: 2035–2045 Autonomous, Intelligent, and Quantum-Resilient Networks

By 2035, NATO's multi-domain network must evolve from a collection of interoperable systems into a smart, self-optimising entity. Artificial Intelligence (AI), autonomous network management, and quantum technologies will drive this transformation.

AI-Augmented Network Management

AI-driven controllers will manage network topologies in real time. These networks will predict and address congestion, autonomously route around jammed or destroyed nodes, and assign optimal waveforms to maintain connectivity during attacks.

Autonomous Resilient Mesh Networks

Autonomy will be embedded within the network itself. SDR nodes, from ground vehicles to UAV relays, will autonomously form resilient mesh networks that remain connected in denied environments, reducing cognitive load on operators.

Quantum-Resilient Communications and Cryptography

Quantum technologies will transform security. Quantum-resistant cryptography will protect sensitive NATO communications from future threats, while quantum key distribution could provide unbreakable links. Integrated via SDRs, these technologies will enable secure, real time information exchange across domains and help prevent cyber compromise.

Blending Space and Commercial Assets

The use of LEO, MEO, and GEO constellations will continue to expand. AI will manage traffic across these transport layers (e.g., tactical, commercial, and strategic), dynamically employing the fastest or most secure route for mission-critical data. In contested scenarios, the system will automatically prioritise sensor-to-shooter traffic over routine updates.

Strategic Implications

By 2045, NATO's advantage will depend on network superiority rather than platforms. Network connectivity will maximise the effect of every sensor and weapon system. The Alliance that successfully integrates SDRs, AI, autonomous networking, and quantum-resistant communications will dominate the future battlespace.

Conclusion: The Bloodstream of Multi-Domain Operations

NATO's deterrence and defence credibility will increasingly depend on the resilience of its connective capability. Multi-domain integration is unattainable with rigid, platform-based systems. It requires a dynamic, resilient, and intelligent communications fabric to connect the Air, Land, Maritime, Space, and Cyber domains.

SDRs are the technical enablers for this convergence, and leadership commitment to this solution is essential for the Alliance's success. The digital and tactical networks that support future operations must be safeguarded, expanded, and optimised. NATO must shift its focus from platforms to networks as the primary enabler. In the multi-domain era, network dominance is as important as raw firepower, and next-generation communications are the new backbone of Air, Land, and Sea dominance. ●



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Deterrence in the Multi-Generational Battlespace

From Westphalia to Hybrid Warfare

By Colonel Will Barksdale, US Air Force, JAPCC

Introduction

In October of 1648, Swedish forces launched a daring assault on Prague, storming its fortifications while Imperial defenders fought desperately to hold the city. Artillery thundered across the Vltava River as disciplined infantry formations clashed in the streets.¹ The battle was brutal yet indecisive; it concluded not with total destruction but with news that diplomats in Münster and Osnabrück had negotiated a settlement. The Peace of Westphalia did more than end the Thirty Years' War; it redefined sovereignty, codified State monopoly on violence, and laid the foundation for the modern international order.² This centralisation of power became the catalyst for military evolution. Only the State possessed the resources to field massive standing armies and sustain industrial

mobilisation, which would characterise subsequent eras of conflict.³

From this state-centric foundation, military theorists have traced the evolution of conflict through five distinct generations, summarised in Table 1. First-generation warfare (1GW) emphasised massed manpower; second-generation (2GW) relied on industrial firepower; third-generation (3GW) prioritised manoeuvre and speed; and fourth-generation (4GW) eroded the state monopoly by introducing non-state actors and insurgency.^{4,5} To this spectrum, scholars now add a theoretical fifth-generation (5GW), which moves beyond physical violence to incorporate grey zone conflict and cognitive manipulation.⁶ While scholars debate the precise boundaries of these generations, the operational reality for NATO is that contemporary adversaries do not select one



The Peace of Westphalia established States as the core unit of international relations.

‘generation’ at a time. The defining characteristic of the modern battlespace is the simultaneous convergence of all five generations of warfare.

This convergence is clearly seen in the Russia–Ukraine war, where the battlespace defies categorisation. Russia continues massing soldiers, employing massed artillery barrages and employing drones from trenches, executing manoeuvre operations on land and in the air, utilising mercenaries such as the Wagner Group, and shaping public discourse through information operations, as illustrated in Figure 1, on page 52.^{7,8}

This Multi-Generational Warfare (MGW) environment strains NATO’s traditional deterrence model. The Alliance is structurally optimised for state-on-state kinetic aggression, yet it now faces adversaries who blend industrial warfare with non-kinetic campaigns to exploit the seams between peace and war. NATO must adapt its deterrence model to this multi-generational reality. The Alliance must integrate non-kinetic domains, irregular warfare, and grey-zone resilience into a coherent framework, while simultaneously maintaining the capacity to fight and prevail in the high-intensity conditions of previous generations. The

Generation	Key Characteristics
1GW	Emphasised massed manpower; linear tactics; close-order formations.
2GW	Relied on industrial firepower; attrition warfare; heavy artillery.
3GW	Prioritised manoeuvre and speed; combined arms; deep operations.
4GW	Eroded state monopoly on violence; introduced non-state actors and insurgency.
5GW	Moves beyond physical violence; incorporates grey zone conflict and cognitive manipulation.

Table 1: *Generations of Warfare.*

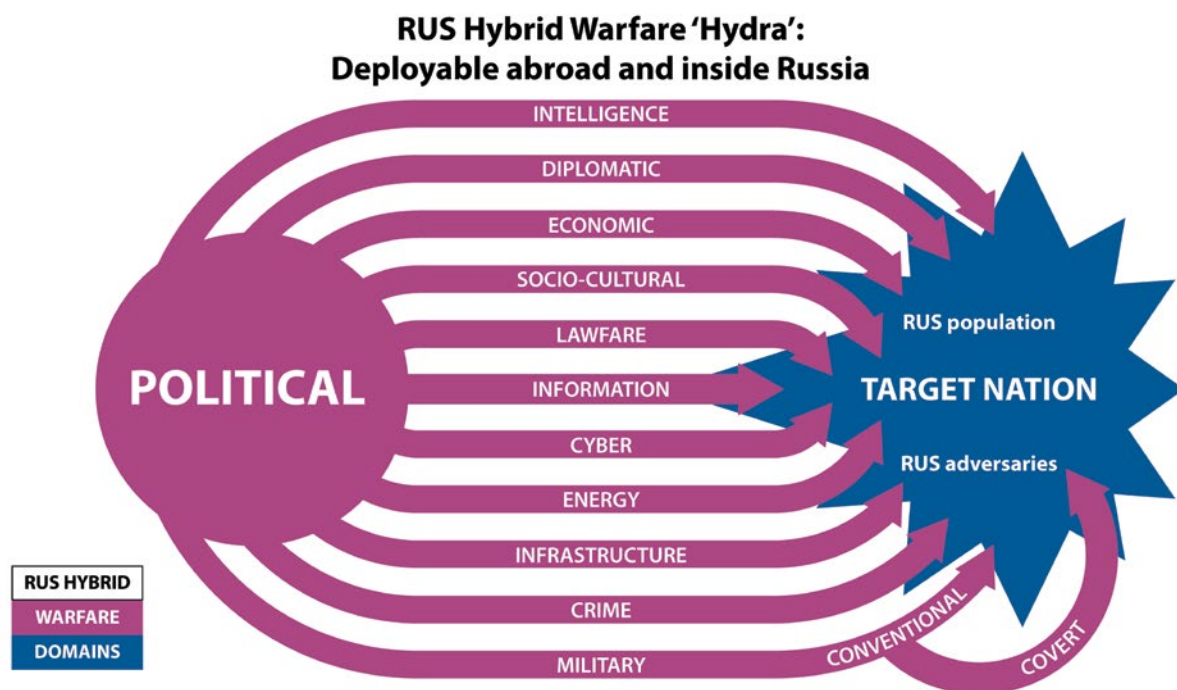


Figure 1: Russia's MGW modalities.²⁴

© Russian Hybrid Warfare modalities. Concept adapted from Mark Voyer's 'RUS Hybrid Warfare "Hydra"'. Graphic recreated by JAPCC.

following sections analyse the evolution of the battlespace, assess the gaps in NATO's current kinetic-focused posture, and propose an integrated deterrence framework that spans the nuclear, conventional, and grey zone spectrum.

The Evolution of the Battlespace

1GW reflected the dawn of the nation-state, relying on massed rank-and-file formations meeting at predetermined times and places. Battles such as those in the English Civil War and Napoleonic Wars were highly controlled and confined to the visual battlefield, where victory often depended on sheer manpower and casualty counts.⁹

This paradigm was shattered by the industrial revolution, and 2GW emerged as rifled muskets, machine guns, and artillery rendered traditional rank-and-file formations suicidal. It was a linear but bloody transition; the early years of World War I demonstrated the lethality of applying 1GW tactics against 2GW technology. In response, armies reduced formation depth, increased width, and relied on centralised, indirect fire to destroy the enemy through attrition.¹⁰

3GW broke the stalemate of attrition by establishing manoeuvre and tempo as central to operational success. This approach required decentralised execution, high-readiness forces, and the ability to outmanoeuvre an aggressor to shatter both their physical and psychological cohesion. World War II epitomises the birth of 3GW, with dispersed operations and deep penetrations across vast theatres.¹¹

'The defining characteristic of the modern battlespace is the simultaneous convergence of all five generations of warfare.'

It was within this 3GW paradigm that NATO found its footing. The Alliance's deterrence posture during the Cold War represented the apex of this model, designed to counter a massive Soviet invasion across the Fulda Gap through superior manoeuvre and rapid reinforcement. However, the post-Cold War era fostered an assumption that high-tech quality had permanently replaced quantity, leading to divestment in mass and the belief that previous generations of war were obsolete.



NATO built its deterrence model around third Generation Warfare.

4GW dismantled this assumption by ending the State's monopoly on war. Emerging prominently after the collapse of the Soviet Union and accelerating after 9/11, 4GW demonstrated that tactical victories and superior firepower no longer guaranteed strategic success. State militaries found themselves engaged with violent extremist organisations (VEOs) and sub-state entities that made political will, rather than terrain, the decisive objective.¹² By expanding conflict into political and social spheres, as seen in the decades-long struggle in Afghanistan, weaker actors circumvented conventional military dominance to impose decisive costs beyond battlefield attrition.¹³

'NATO's deterrence model is largely binary. It is designed to switch from peace (white) to war (black) upon the triggering of Article 5. Adversaries understand this threshold and deliberately operate below it, creating the grey zone gap.'

5GW, or grey-zone conflict, further dissolves the lines between peace and war. While 4GW introduced non-state actors, 5GW sees State actors weaponising ambiguity. This shift became undeniable during the 2014 annexation of Crimea, where 'little green men' achieved strategic goals without triggering a conventional response. Beyond land, sea, air, and space, 5GW targets politics, culture, values, data, leadership, morale, and

perceptions.¹⁴ Its central aim is to 'win without fighting' – a principle long articulated by Sun Tzu – by operating below the West's recognised threshold of armed attack. As illustrated in Table 2, adversaries employ a spectrum of non-military tools, from economic coercion to legal warfare. These methods underscore the complexity of 5GW, where victory hinges on shaping narratives and eroding trust rather than seizing terrain.

The Multi-Generational Reality: Convergence and Simultaneity

The defining challenge of the contemporary security environment is not the existence of these five generations, but their simultaneity. In the past, military theory assumed a sequential progression from one generation to the next. Today, that logic is obsolete. Adversaries do not select a single generation of warfare. They employ an MGW strategy that additively applies capabilities to exploit specific vulnerabilities. For NATO, this presents a dilemma in generating an appropriate response. An adversary may use 5GW modalities to destabilise a region politically, avoiding attribution, while simultaneously massing 2GW artillery on the border to deter intervention and threaten high operational costs. This 'full-spectrum' approach is designed to paralyse decision-making by overloading the defender's ability to classify the threat. Is it a riot? Is it an invasion? Is it a diplomatic crisis? By the time NATO categorises the threat, the adversary has often already achieved its objective.

Type of Warfare	Description
Psychological Warfare	Spreading rumours to intimidate the enemy and break down his will.
Smuggling Warfare	Throwing markets into confusion and attacking economic order.
Media Warfare	Manipulating what people see and hear to influence public opinion.
Drug Warfare	Obtaining sudden and huge illicit profits by spreading disaster in other countries.
Network Warfare	Venturing out in secret and concealing one's identity in a type of warfare that is virtually impossible to guard against.
Technological Warfare	Creating monopolies by setting standards independently.
Fabrication Warfare	Presenting a counterfeit appearance of real strength before the eyes of the enemy.
Resources Warfare	Grabbing riches by plundering stores of resources.
Economic Aid Warfare	Bestowing favour in the open and contriving to control matters in secret.
Cultural Warfare	Driving cultural trends along in order to assimilate those with different views.
International Law Warfare	Seizing the earliest opportunity to set up regulations.

Table 2: *Types of 5GW described in 'Unrestricted'. Published in 1999 by Beijing's PLA Literature and Arts Publishing House.²⁵*

The Strategic Gap: Kinetic Deterrence in a Grey Zone World

This multi-generational reality exposes a structural fissure in the Alliance's deterrence posture. NATO's current framework remains optimised for high-intensity, state-on-state conflict, leaving it firmly anchored in the legacy of 3GW and the Cold War era. The Alliance's 2022 Strategic Concept reaffirms a posture built on nuclear capabilities, forward-deployed conventional forces, and collective defence under Article 5.¹⁵ While these pillars remain essential for preventing a 3GW operational collapse or nuclear escalation, they are ill-suited for the lower-intensity spectrum of 4GW and 5GW. NATO's deterrence model is largely binary. It is designed to switch from peace (white) to war (black) upon the triggering of Article 5. Adversaries understand this threshold and deliberately operate below it, creating the grey zone gap. Actors such as Russia exploit the ambiguity of 5GW to achieve strategic gains without ever tripping the wire of collective defence. Crucially, this grey-zone strategy is directed against NATO's

political centre of gravity, namely the consensus model. Article 5 is a political decision, not an automatic trigger. By operating in the realm of ambiguity 5GW represents, adversaries obscure the attribution required to generate political consensus among 32 nations. If the Alliance members cannot agree on who is attacking NATO, it cannot hope to agree on how to respond.

NATO leadership has recognised this vulnerability. Recent strategic advances, such as the Concept for Deterrence and Defence of the Euro-Atlantic Area (DDA) and the NATO Warfighting Capstone Concept (NWCC), clearly identify these hybrid threats and emphasise a '360-degree' approach to security. However, while the concepts are sound, the Alliance's practical toolkit for responding to non-kinetic aggression remains underdeveloped when compared to its robust kinetic warfighting plans. This leaves a gap where adversaries can manoeuvre with relative impunity, confident that their actions will not generate the clarity required to trigger a unified Alliance response.

Adapting the Framework: A Functional Approach

NATO's adaptation must move beyond a simple shopping list of capabilities. To deter effectively across multiple generations of warfare, the Alliance requires a functional framework that organises its response into three distinct pillars: Orchestration, Resilience, and Contestation.

1. Orchestration: Solving the MDO Challenge

The primary challenge of MGW is the sheer volume of activity. NATO must accelerate the implementation of its Multi-Domain Operations (MDO) concept to act as the central nervous system for the MGW environment.

- **Civ-Mil Integration:** MDO, by its nature, is not purely military. In 5GW, the 'terrain' is often civilian owned, including digital banks, energy grids, and social media platforms. Therefore, NATO's command and control must integrate civil and military data streams to visualise the 5GW battlespace.¹⁶
- **AI-Enabled Speed:** Orchestration requires processing power. Leveraging artificial intelligence for predictive analysis will allow commanders to sift through the noise of hybrid campaigns and identify the adversary's main effort, yielding an operational tempo advantage.¹⁷

2. Resilience: The 'Shield' of Deterrence

To deny adversaries the easy gains they seek in the Grey Zone, NATO must harden the soft targets of democratic society to achieve deterrence by denial.¹⁸

- **Layered Resilience:** Deterrence is no longer just about tanks on the border. It is about the ability of a society to absorb shock. This requires a wide range of civilian structural changes, such as hardening critical cyber networks, securing transport and energy infrastructure, and strengthening supply chains.¹⁹

- **Cognitive Defence:** Resilience must extend to the mind. Adversaries militarise information to fracture Alliance cohesion. Countering this attack vector requires proactive and persistent strategic communications and meaningful education, rooted in Western values, which inoculates populations against disinformation before it takes root.^{20, 21}

'In this evolving environment, adversaries exploit the ambiguity of 5GW, weaponising subtlety to circumvent NATO's established strengths and undermine Alliance cohesion.'

3. Contestation: The 'Sword' in the Grey Zone

Finally, NATO must close the grey-zone gap. Deterrence fails if the adversary believes NATO has no response options short of total war.

- **Irregular Warfare Capabilities:** NATO must institutionalise irregular warfare competencies. Special Operations Forces (SOF) and intelligence elements must be empowered to compete in the grey zone by conducting counter-proxy operations and exposing adversary activities without necessarily triggering a full kinetic war.²²
- **Attribution as a Weapon:** The greatest enemy of 5GW is transparency. NATO must invest in rapid attribution mechanisms that strip away the adversary's plausible deniability. By publicly attributing cyber or hybrid attacks quickly and accurately, NATO denies the enemy the ambiguity they need to fracture political consensus.²³

Conclusion

The MGW framework is not merely an academic construct. It provides a vital diagnostic lens for reevaluating the Alliance's security posture. While NATO remains well-prepared to counter the high-intensity kinetic threats associated with earlier generations of warfare

(1GW – 3GW), its resilience is increasingly tested by the simultaneous convergence of contemporary challenges. In this evolving environment, adversaries exploit the ambiguity of 5GW, weaponising subtlety to circumvent NATO's established strengths and undermine Alliance cohesion. To navigate this complex landscape, NATO must move beyond incremental capability upgrades and embrace a functional framework for integrated deterrence. This evolution should rest on three interdependent pillars: orchestration, resilience, and contestation. Orchestration will enable the Alliance to manage the simultaneity of the modern battlespace, synchronising

effects across kinetic and non-kinetic domains through MDO. Resilience will deny adversaries the easy wins of 5GW by hardening the societal and digital foundations that underpin military power. Contestation will ensure NATO can compete effectively in the grey zone, imposing costs on adversaries before they escalate to armed conflict. Ultimately, a multi-generational approach that integrates nuclear, conventional, and grey-zone instruments is essential to restoring deterrence credibility. By doing so, NATO will reaffirm its role not as a relic of the Cold War, but as the cornerstone of Euro-Atlantic security for decades to come. ●

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Colonel Will Barksdale commissioned into the US Air Force in 2006 from Mississippi State University, graduated from ENJJPT in 2007, held instructor pilot qualifications in both the T-38 and F-22, and has been involved in the production of 350 F-22 pilots. He has deployed to the Indo-Pacific region as part of theatre security packages and commanded both an aircraft maintenance and a fighter squadron. He is a graduate of Air Command and Staff

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JOINT WARFARE CENTRE



Centralised Command, Distributed Control, Disconnected Training?

Why a Unified Battle Management Architecture is Key to NATO's Distributed Operations and Training

By Commandant Peter Vanderostyne, BEL Air Force, JAPCC

Introduction: A New Mantra in Multi-Domain Operations

With the outbreak of the Ukraine-Russian conflict, we have witnessed fundamental paradigm shifts in how modern warfare hinges on distributed and dispersed operations. Traditional conventional operations, though still conceptually valuable, are increasingly struggling to meet the demands of contemporary conflict. Precision strike threats, persistent ISR, electronic warfare, cyber disruption, multi-domain

integration, and compressed decision cycles shape today's battlespace.

In this rapidly evolving battlespace, NATO confronts adversaries who leverage speed, ambiguity, and disruption across every domain, Land, Sea, Air, Cyber, and Space. As noted by Generals Mark Milley and Stephen Townsend, 'Commanding across these domains requires an evolution from 20th-century Command and Control (C2) methodology to one that provides Decision Advantage in the rapidly changing environment.'¹

To maintain superiority, our C2 architecture must match this agility. The emerging doctrine of Centralised Command, Distributed Control, and Decentralised Execution signifies this crucial transformation, balancing unity of effort, operational resilience, and tactical initiative.



The Joint Warfare Centre is modernising NATO's largest exercises by employing technologies like the Maven Smart System, the Alliance's first AI-enabled warfighting command-and-control capability.

However, this approach presents a C2 dilemma. NATO faces three interconnected challenges: maintaining unity of effort across contested communication channels; translating the hard-won lessons of Ukraine into a coherent battle management architecture; and ensuring that synthetic training environments genuinely reflect the principle of 'train as you fight.' From the perspective of multi-domain operations (MDO), this article will analyse how a unified battle management interface integrates disparate data sources, including multi-tactical data links (TDL), into a single operational picture. These are critical training components that must be integrated into a cohesive battle management system. Ultimately, it asserts that NATO requires a Unified Battle Management Architecture, a hardware-agnostic software framework that fuses multi-domain sensor data into a single, actionable interface for both the warfighter and the trainee. Without this, we risk a 'disconnected' force that possesses the tools for victory but lacks the muscle memory to use them in a contested environment.

Essential Elements Fostering Decisional Advantage:

The Cognitive Dimension and Centralised Command

Decision advantage in modern warfare increasingly hinges on the cognitive dimension, the ability to interpret and act amid uncertainty. As data saturates the battlespace, cognitive overload becomes a critical risk.² Centralised Command remains the cornerstone of NATO's strategic coherence in managing this complexity. At the highest level, it ensures that operations, whether reinforcing the Baltics, securing Mediterranean Sea lanes, or defending against cyber intrusions, align with the Supreme Allied Commander Europe's (SACEUR) intent.

'Effective Distributed Control in contested environments requires NATO to align its doctrine with its technology through a unified battle management software interface, one that is used for both training and operations.'

This centralisation is not about micromanaging every move, but rather, safeguarding unity of effort, prioritising resources, and preventing strategic fragmentation. During Exercise DEFENDER 25, the largest US Army exercise in Europe, Centralised Command was vital to stress-test NATO's ability to synchronise logistics, airlift, Cyber defence, and multinational operations under a single strategic vision.³

Resilience through Distributed Control and Decentralised Execution

Centralisation alone cannot withstand adversaries who target command nodes through cyberattacks, electronic warfare, or precision strikes. This is where Distributed Control becomes critical. By dispersing planning, monitoring, and coordination across multiple resilient nodes, NATO mitigates the risk of single points of failure. If a primary headquarters is disrupted



The Command and Control Duty Officer (C2DO) in a Joint Force Air Component (JFAC) may send preformatted Link 16 messages such as engagement orders in real-time. This will inform the entire crew on board.

by a Cyber breach, regional commands and battle management centres can continue directing operations without interruption.

Exercise STEADFAST DUEL 2025 was the first operational-level NATO exercise to implement these distributed concepts at scale. It connected NATO's operational commands in a simulated 24/7 battlespace which mirrored the complexity of modern conflict. Participants trained day and night, adjusting their battle rhythm to strengthen NATO's ability to plan, coordinate, and fight as one Allied force across all domains.⁴

At the tactical edge, Decentralised Execution empowers operators to act with speed and initiative. Whether a fighter squadron adjusts its tactics mid-sortie due to unexpected air defences, or a naval task group exploits an opportunity to interdict hostile vessels, decentralisation ensures that decisions occur at the speed of relevance. In contested environments, waiting for higher-level approval is not an option. Initiative on all fronts is the key to maintaining dominance.

Digitalisation and AI-Enabled Decision-Making

The success of NATO's MDO relies on two interconnected pillars: digitalisation and interoperability. Digitalisation enables seamless data collection and

processing through advanced technologies like cloud computing, AI, quantum systems, and 5G.

While AI may seem the logical choice for swift decision-making, it must be paired with legal considerations in line with the law of armed conflict (LOAC). Artificial intelligence (AI) mitigates cognitive overload by filtering, fusing, and prioritising sensor inputs, enabling faster and clearer decision-making than adversaries.⁵ AI tools highlight anomalies, anticipate threats, and synthesise outcomes, allowing commanders to make rapid and confident decisions.⁶

The use of the NATO Maven Smart System (MSS) during STEADFAST DUEL demonstrated AI-enabled C2 in distributed decision-making. MSS integrates large language models and machine learning to consolidate siloed data sources into a unified and secure software platform. The swift six-month procurement process for MSS underscores NATO's recognition of the urgency in deploying disruptive technologies to enhance operational agility.⁷

The Evolving Commander's Intent

The operational environment requires an adaptable commander's intent that enables mission execution under degraded communication conditions and

information saturation. Beyond task orientation, it must encompass survivability measures and the mitigation of vulnerabilities arising from electronic warfare competition. Central to this is signature management, the systematic reduction of physical, electromagnetic, acoustic, thermal, and cyber emissions that adversaries exploit for targeting.

These factors indicate that a NATO mission commander must possess capabilities far beyond traditional joint operations. They must coordinate military actions across all five operational domains, synchronised with non-military instruments of power, to achieve converging effects at the speed of relevance.⁸

'We must treat our data links and battle management architectures as weapon systems that require constant, high-fidelity exercise.'

However, the resilience of distributed control is only as strong as the proficiency of the operators managing it. If the tools used in high-end synthetic training environments do not mirror the complexities of the live environment, particularly regarding TDL contention and jamming, we risk a cognitive disconnect. This is where the gap between NATO's current training systems and the requirements of a unified architecture becomes most apparent. To understand how to bridge this gap, we must look at current operational models.

Delta vs. CRC System Interface: Two Paths to C2 Excellence

To understand the evolution of NATO's Battle Management, we must examine two distinct yet increasingly convergent models: Ukraine's Delta system and NATO's Control and Reporting Centre System Interface (CSI). While their objectives of speed and resilience are shared, their underlying design philosophies offer distinct advantages for the Alliance.

Ukraine's Delta C2 system exemplifies a cloud-based, decentralised architecture that integrates real-time data from drones, satellites, and sensors. It serves as a unified data exchange platform across devices at all command levels, maintaining operational tempo even under the stress of cyberattacks or heavy electronic jamming.⁹ During Exercise REPMUS 2025, Delta coordinated more than 100 unmanned platforms across the Maritime, Land, and Air domains, demonstrating remarkable resilience in contested environments. Deputy Minister Myronenko emphasised that while long-range systems require complex planning cycles, Delta's dispersed nodes enable near-real-time front-line responses, significantly reducing the 'sensor-to-shooter' timeline from days to minutes.¹⁰ This success underscores a critical lesson: in an era where seconds matter, resilience stems from the ability to automate workflows and disperse control across a survivable network.

In contrast, NATO's Control and Reporting software, CSI, demonstrates the Alliance's structured, integrated approach to air C2. This NATO nations' hardware-software platform employs standardised multi-tactical data link protocols, such as Link-16, Link-11B, Variable Message Format (VMF), and Joint Range Extension Applications Protocol (JREAP), to ensure interoperability among aircraft, air defence systems, and command centres. CSI enables real-time mission coordination and a shared operational picture across fighter aircraft, Surface-Based Air and Missile Defence (SBAMD) units, and joint C2 platforms. With its unique governance structure, in which SHAPE also participates as a member state, NATO Communications and Information Agency (NCIA) developed a modular CSI software solution that effectively combines interoperability with cost efficiency.

Beyond its military utility, CSI supports the integration of ATC radars, meteorological data, and Air Traffic Management systems, aligning with Single European Sky ATM Research (SESAR) standards. By operating as a fully integrated solution rather than relying on the CRC as a 'middleman', CSI reduces dependency on voice communication and enhances operational safety through civil-military coordination. Furthermore, it processes critical non-real-time planning directives,



This CSI screenshot highlights enhanced situational awareness enabled by Link 16 over Internet Protocol via JREAP-C. By leveraging Tactical Data Links, operators no longer rely solely on radio communication. Instead, they gain immediate access to critical information, such as surveillance data, type of platform, flight parameters, engagement orders, weapons status, and free text messages, delivered in real time for all operators in the TDL network.

notably the Air Tasking Order (ATO) and Airspace Control Order (ACO), which govern the allocation of missions and the deconfliction of airspace. While Delta excels in the 'bottom-up' agility of the front line, CSI ensures the 'top-down' precision and unity required for complex coalition air operations.

Although not used in practice, Ukraine's adoption of CSI could further enhance joint NATO operations. Integrating the structured interoperability of the NATO standard with the agile, decentralised approach of Delta could yield a hybrid model that combines tactical adaptability with the strategic coherence required for future Alliance missions. Moreover, Delta's dispersed control philosophy allows operators to coordinate and execute tasks from virtually any device, laptops, smartphones, or desktop systems, ensuring continuous operational resilience even in highly contested environments.

Closing the Proficiency Gap: The Training Imperative

The technical sophistication of systems like Delta and CSI reveals the importance of data-driven and decentralised operations. However, as noted in recent iterations of Exercise STEADFAST DUEL, a persistent training gap remains. While our operational

architecture is evolving, the synthetic environments we use to prepare our forces often remain disconnected from reality.

Currently, the CSI simulation suite effectively replicates operational conditions for certain ATO execution tasks. However, simulated Article 5 scenarios in the STEADFAST series of exercises can sometimes become audience-driven rather than operationally realistic. A gap analysis of recent exercises reveals that tactical decisions would differ significantly if participants were forced to contend with real-world technical limitations, such as multi-TDL contention or hostile jamming. In a dispersed fight under high-stress conditions, an operator cannot be expected to remain proficient if their training software differs from their operational interface, or if the training environment is 'sanitised' of the electronic warfare complexities they will face in the field.

Effective Distributed Control in contested environments requires NATO to align its doctrine with its technology through a unified battle management software interface, one that is used for both training and operations. Exercise UEDEM AWAKENING 2025 demonstrated the value of this approach through a Danish Air Control Wing initiative that integrated operators from the Swedish Air Force (SAM Allocators) and the Royal Danish Navy (AAW) by utilising Link 16 simulators and procedures for



Air traffic specialists analyse real-time radar data to monitor designated airspace sectors, ensuring safe separation and efficient routing for all aircraft.

Integrated Air and Missile Defence (IAMD) weapons coordination and engagements, while exchanging the Common Operational Picture (COP) through Link 16 over JREAP-C. By treating TDL switch actions and network management as integral combat skills rather than specialist tasks, NATO can build the muscle memory required for combat readiness in MDO. Synchronising higher headquarters with CRC levels and expanding CSI training for both staff and operators will be vital to reinforcing the train as you fight principle.

Finally, the comprehensive integration of EUROCONTROL's Air Traffic Management data and Airspace Management data into CSI provides an additional operational advantage. When seamless data exchange is trained and prioritised over traditional voice communications, decisions regarding IAMD procedures can be made more rapidly, ultimately contributing to safer and more secure airspace in peacetime, crisis, and conflict.

The Road to 2030: The NATO Digital Backbone

As we look toward the future, the NATO Digital Backbone serves as the Alliance's 'North Star' for this C2 transformation. Often mentioned but rarely defined in

detail, the Digital Backbone is the federated connectivity and data-transport framework designed to enable MDO by 2030. It is intended to provide a secure, scalable 'cloud-first' environment that interconnects sensors, decision-makers, and effectors across all domains and civilian mission partners.

The Digital Backbone is not just a hardware upgrade; it is a resilience architecture. It integrates advanced cybersecurity, data fabric services, and AI-enabled decision tools into a single, interoperable ecosystem. While the cutting-edge C2 technologies being matured through experimentation today are impressive, we must recognise that MDO is occurring now. The Digital Backbone provides the technical foundation, but its success depends entirely on the proficiency of the personnel operating within it.

Conclusion: Synchronising Architecture and Action

The conflict in Ukraine has provided a humbling reminder that the side that can fuse data and execute decisions fastest holds the advantage. NATO's transition toward Centralised Command, Distributed Control, and Decentralised Execution is the correct

doctrinal response to this reality. Systems like Delta and CSI provide the architectural blueprints for this new way of war, offering the speed and interoperability necessary to secure Allied interests.

However, technical superiority is a hollow advantage if it is not matched by realistic preparation. We cannot afford to have a disconnected force that possesses the tools for victory but lacks the routine practice required to use them in a contested environment. To achieve true Decision Advantage, NATO must bridge the gap between its operational systems and its training simulations. We must treat our data links and battle management architectures as weapon systems that require constant, high-fidelity exercise.

The NATO Digital Backbone will provide the infrastructure, but our commitment to the train as you fight principle will provide the edge. As this new mindset takes hold across the Alliance, we must act now to seize every opportunity to build muscle memory, synchronise our efforts, and ensure that when the next crisis emerges, NATO is not just technically ready, but operationally dominant. ●

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Assistant to the Commander, CAOC UE. He supported NATO missions, including Allied Force, Deliberate Guard, ISAF twice, Baltic Air Policing, Eagle Assist, and Unified Protector. Renowned for expertise in Battle Management and Airspace Planning, he pioneered Afghanistan's first Common Operational Picture and revolutionised frequency management from monthly to daily assignments, strengthening NATO's operational agility. Having witnessed interoperability shortcomings during operations, he continues, as a reservist, to support efforts with JAPCC, HQ AIRCOM, and HQ ACT to establish a NATO Joint Interoperability Division and Data Link Training Centre to enhance decision superiority across the modern battlespace.

Wargaming the Complex Battlespace

Rethinking Targeting for Multi-Domain Operations

By Mr Adam T. Jux, BA Civilian Targeting Consultant

By Dr Christopher J. Morris, PhD Civilian Wargaming Contractor



Introduction

Targeting is central to offensive military operations. NATO's Allied Joint Doctrine for Joint Targeting (AJP-3.9) states that joint targeting links tactical actions to operational and strategic objectives.¹ Contemporary Air Domain targeting must cope with adaptive adversary systems and networks in which kinetic and non-kinetic effects interact in non-linear ways. Models inherited from earlier conflicts are increasingly inadequate when confronted with the realities of the

modern battlespace, which is congested, cluttered, contested, connected and constrained.² To address this complexity, NATO should adopt analytical wargaming as a permanent learning cycle. This would allow planners to test targeting hypotheses in a 'safe-to-fail' environment, ensuring that proven decision logic informs future doctrine and operational planning.

The ongoing conflicts in Ukraine and the Middle East illustrate how legacy targeting models struggle against complex adaptive systems. In Ukraine, relatively modest

capabilities, integrated into a software-defined architecture, have repeatedly frustrated a numerically superior adversary.³ By dispersing mobile ground-based air defence systems and leveraging commercial ISR, Ukrainian forces successfully complicated the Russian targeting cycle, proving that success depends less on platform superiority than on the speed of tactical adaptation.⁴ This outcome is not solely attributable to Western-supplied weapons systems, but to how Ukraine adapted its Tactics, Techniques, and Procedures (TTPs).

'In theory there is no difference between theory and practice. In practice, there is.'

Jan L. A. van de Snepscheut

Operations against the Iran-aligned Houthi movement, Ansar Allah, a non-state armed group in Yemen, present a different targeting challenge and demonstrates the limits of conventional deterrence.⁵ As a decentralised non-state actor, the Houthis leverage transnational support networks and operate within civilian populations to insulate themselves from traditional strikes. This asymmetric 'Red Sea Model' shows that Western advantages in precision munitions are often negated by an adversary's ability to absorb high-end kinetic effects while maintaining persistent maritime disruption. NATO currently lacks a 'safe-to-fail' environment in which to analyse how isolated tactical decisions reverberate across a long-term campaign. Analytical wargaming provides that space, allowing practitioners to explore second-order effects before a single mission is launched.

Wargaming as an Analytical Framework

Wargaming offers a powerful tool for analysing complex systems and can help reveal how behaviours and external factors can influence outcomes rather than predict them. In NATO usage, a wargame is a decision-centric simulation in which players act under friction and receive feedback, conducted either for learning or

analysis.⁶ NATO doctrine addresses the use of wargaming in Allied Joint Publication, AJP-5, as a means for conducting course of action (COA) analysis and evaluating decision points for branches and sequels. While COA wargaming is the most familiar doctrinal application, it represents only one point on a wider spectrum of wargaming practice. Wargaming can be leveraged at each – strategic, operational, and tactical – echelon and across time horizons, from fight tonight and COA analysis to long-range force development and concept testing decades into the future.

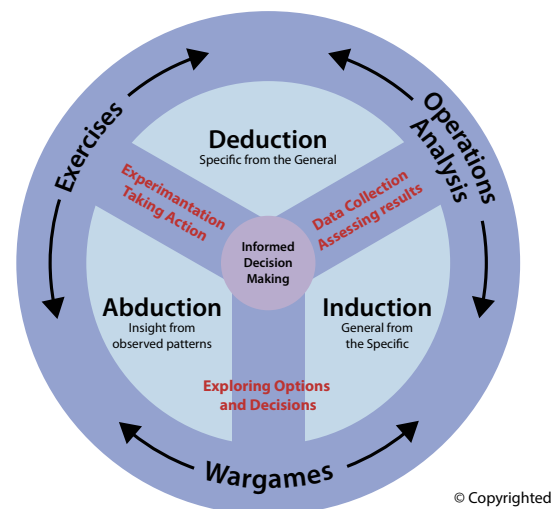


Figure 1: Adapted from Perla, 'The Art of Wargaming'

Professional military wargaming provides a means to iterate processes or functions to develop a clearer understanding of potential outcomes and to inform plans, TTPs, and doctrine. Peter Perla's Cycle of Research proposes that wargaming, exercises, and operations analysis should function in a continuous cycle, incorporating real-world operations and historical data, to help the national security community understand real world events.⁷ This cyclic nature is important because it positions wargaming as part of an organisational learning system, rather than merely an event.

Wargaming is dependent on human decision-making. Its distinctive value is data derived from how participants perceive, choose, and adapt under constraints. This human element distinguishes wargaming from quantitatively focused modelling and

simulation, where the decision is removed and attention shifts to a range of outcomes derived from a given set of variables.

Some wargame designs incorporate probabilities, data, and structured adjudication to inform outcomes. Others rely primarily on facilitated discussion and expert judgement to surface assumptions and generate qualitative insights. In both cases, the decisive mechanism is the same: the human participant is the agent that creates the game's most important data, decisions made under friction and the reasoning behind them.

Unfortunately, NATO targeting has not yet fully exploited this spectrum, tending to treat wargaming primarily as a training event rather than as a repeatable research method that produces transferable insight for doctrine and planning.

From COA Analysis to Informing Experience

In analytical wargames, human players are a critical input used to explore hypotheses and capture decision logic. In educational wargames, the human experience is the intended output, shaping understanding and professional judgement. Wargaming provides a safe-to-fail environment that allows participants to encounter friction, to test bold strategies, challenge assumptions, and explore unconventional approaches without professional and existential risk.⁸ Less constrained by resources and operational limitations, wargame designers can manipulate time and space to expand the depth of analysis. A months-long campaign can be examined in days, and a single targeting cycle can be drawn out over a week of gameplay, executed from virtually anywhere.

Learning objectives can tailor the focus of the event, and adversary perspectives can move beyond dogmatic generalisations and be examined in detail. Critically, the value lies not only in what happened in the game, but why players made the choices they did. When analytical wargames are treated as learning tools, outcomes should drive discussion and

assessment rather than recrimination, building institutional knowledge about system behaviour, cascading effects, and adaptive responses that persist beyond individual participants.

These benefits are not automatic. They depend on design quality and appropriate interpretation. A deliberate design process differentiates professional military wargaming from ad hoc COA analysis or tabletop mission rehearsal. The methods dictate the outcomes. Adjudication rules and player behaviour can produce vastly different results from the same scenario. Conversely, haphazard assumptions and inputs from the facilitation and adjudication team can shift a wargame into the realm of fantasy.

Most importantly, wargame outcomes can mislead if treated as predictive tools. Biases and classification constraints can hinder the friction inputs, and resource-intensive games are difficult to repeat regularly. Due to the human and decision-centric nature of wargaming, it is impractical to assume representative sample sizes capable of producing predictive or probabilistic conclusions. Wargaming complements, rather than replaces, other analytical tools such as modelling and simulation and field exercises. Each method should be selected to match the question being asked.

NATO Wargaming for MDO Targeting

Methodological framing becomes more urgent as NATO attempts to operate in a genuinely multi-domain environment. NATO seeks to become a Multi-Domain Operations (MDO) enabled force by 2030, but the concept remains unevenly understood across the Alliance. MDO is not limited to the five conventional domains of Air, Land, Maritime, Space, and Cyber. It also involves non-lethal instruments and wider governmental and societal influences that shape strategic outcomes. Expanding wargaming to incorporate non-lethal and cross-domain targeting considerations would better align analytical learning with NATO's MDO ambitions.⁹

Integrating MDO-type targeting into wargaming presents distinct analytical challenges across targeting types. Non-lethal targeting, dynamic targeting, and



Wargaming offers a powerful tool for analysing complex systems and can help reveal how behaviours and external factors can influence outcomes rather than 'predict' them.

deliberate targeting each require different game design parameters to assess effectiveness. For instance, a matrix wargame is an argument-based tabletop simulation governed by discussion rather than complex rules. It can explore the integration of non-lethal effects alongside kinetic operations and examine trade-offs, sequencing, and unintended interactions. At the military-strategic level, campaign-length wargames can explore how targeting strategies interact with political objectives, alliance dynamics, and adversary grand strategy. Here, second- and third-order effects, such as escalation risk, legitimacy, alliance cohesion, and freedom of action, become central to the targeting problem.

Unlike most exercises, strategic wargames prioritise decision-making under uncertainty over tactical proficiency. Because political objectives and constraints govern military action, targeting must account for where lethal operations and non-lethal effects – economic, political, and informational – interact or conflict. Military action must either complement the effects sought at the political level or, at minimum, avoid undermining them. It is inefficient, for example, to invest in Signals Intelligence (SIGINT) collection against a facility only to conduct a lethal strike the next day, unless this strike resulted from an MDO-informed effects logic and sequencing plan.

Wargaming Application Across Echelons

Educational wargaming remains common at the operational level, primarily to teach concepts, foster critical thinking, and strengthen decision-making skills. However, operational- and strategic-level wargaming increasingly emphasise analytical applications that generate data and explore broader questions of doctrine, capability, and force structure.¹⁰ Embedding wargaming within the institutional learning cycle, thereby creating feedback loops between operational experience and doctrinal development, should be treated as a concrete institutional objective, not merely an aspiration.

This institutional approach matters because it clarifies what NATO seeks from the activity: learning outcomes, analytical findings, or both. Current analytical wargames can focus on specific hypotheses concerning targeting effectiveness, adversary behaviour, or system performance, with results feeding into doctrine development and operational planning cycles. Over time, this would create an empirical foundation for understanding targeting in complex environments and help characterise and manage uncertainty that emerging technologies and evolving adversary behaviours create. Across the military-strategic, operational, and tactical echelons, analytical applications serve different



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Embedding wargaming within the institutional learning cycle, thereby creating feedback loops between operational experience and doctrinal development, should be treated as a concrete institutional objective, not merely an aspiration.

purposes and should be deliberately programmed and linked with the appropriate audiences.

At the military-strategic level, campaign wargames explore how targeting strategies across multiple Joint Operational Areas (JOAs) interact with political objectives, alliance dynamics, and adversary grand strategies. The focus at this level is on commander decision-making dilemmas rather than tactical proficiency or training outcomes. Human judgement remains central, but AI-enabled tools may support strategic-level wargaming by improving data capture and expanding the decision spaces available for analysis.

Operational-level wargames should analyse system-level interactions and build shared understanding of the targeting process. Operational staffs can test specific targeting challenges within limited, defined scenarios. These might focus on counter-air operations in contested environments, interdiction campaigns against adaptive networks, or close air support in urban terrain. The emphasis is to understand how targeting systems

support prioritisation of targets and the achievement of an end state rather than training individual skills.

At the tactical level, wargaming explores decision-making challenges within the targeting process. These may examine sensor-to-shooter timelines in dynamic environments, the effectiveness of different munitions against adaptive targets, or coordination challenges between manned and unmanned platforms. While wargames can explore decision logic, designers should tightly scope technically adjudicated elements and, where necessary, pair with modelling and simulation or validated data.

Specialist analytical wargaming would first explore how targeting processes can adapt and evolve. Designers should use targeting experts in deliberate, dynamic, and non-lethal targeting to shape wargame development. The findings would then inform educational wargaming incorporated into exercises by translating findings into teachable decision patterns, planning norms, and scenario injects. In turn, this would

inform training design tailored to the echelon and audience, each with distinct authorities, responsibilities, and measures of effectiveness. This institutional 'analysis-to-education' pipeline is particularly important as emerging capabilities complicate targeting by compressing time, expanding target sets, and increasing cross-domain interaction effects, conditions that render linear targeting models increasingly brittle.

Recommendations for Integrating Targeting into Wargaming

To operationalise the analytical benefits of wargaming, NATO must move beyond recognising challenges and towards institutional solutions. The following recommendations provide a framework for integrating wargaming into the NATO targeting enterprise:

1. Leverage the Distributed Synthetic Training (DST) Initiative. The October 2024 launch and subsequent October 2025 Memorandum of Understanding (MoU) for the DST initiative provide the ideal technical architecture for analytical wargaming. Rather than building isolated 'wargaming rooms', NATO should use the DST framework to federate national wargaming efforts. This allows for high-fidelity, cross-domain targeting scenarios to be executed virtually across Allied borders, mitigating the physical and resource constraints of traditional tabletop exercises.
2. Identify a network of organisations as the lead centres for 'Synthetic Targeting' efforts. To address manning and expertise gaps, NATO should designate specific hubs to lead targeting wargaming development. JAPCC should serve as the conceptual lead for Air-Domain analytical wargaming, while the Joint Warfare Centre (JWC) in Norway and the Joint Force Training Centre (JFTC) in Poland should be empowered to host and adjudicate campaign-level targeting wargames. These centres should act as the 'repository of decision logic', ensuring that lessons learned in one exercise are captured and distributed across the Alliance.
3. Address 'Time-Compression' through Hybrid Design. The challenges posed by hypersonic systems, AI-

driven autonomy, and Cyber effects share a common theme: compression of the decision window. NATO should move toward 'Hybrid Wargaming' models that combine traditional human-in-the-loop decision-making with AI-enabled adjudication tools. This enables safe-to-fail testing of delegated authorities, determining when and where human oversight is required before these high-speed systems are fielded in a live environment.

4. Normalise Experimental Evaluation. NATO must decouple wargaming outcomes from performance scoring. Commanders require the 'intellectual manoeuvre space' to test unconventional targeting strategies without the fear of poor evaluation. Wargaming should be treated as an experimentation laboratory where a loss is regarded as a high-value discovery for doctrine and experience. This cultural shift is essential for mastering MDO, where the interactions between lethal and non-lethal effects are non-linear and often unpredictable.
5. Standardise Cross-Domain Data Capture. To solve the 'Multi-Level Security Paradox', NATO should prioritise the development of standardised Cross-Domain Solutions (CDS), that enable secure, controlled, and audited data transfers between different security domains within the wargaming architecture. This would allow for the integration of sensitive Cyber and Space effects into broader targeting wargames without compromising national classification caveats, a prerequisite for realistic MDO training.

Conclusion

NATO should reframe wargaming not as an occasional training event, but as a repeatable learning and research method that generates evidence for planning and doctrine. That shift requires two practical changes: disciplined wargame design tied to clear analytical questions, and routine findings captured, assumptions tested, decisions taken, and effects observed, so lessons do not remain anecdotal.

This matters because NATO's doctrine development cycle is inherently political and often slow to absorb

operational feedback. Institutionalising analytical wargaming as a feedback loop, supported by appropriate digital tools including AI-enabled data capture and analysis, can help translate insights into usable products: refined targeting concepts, updated TTPs, and clearer guidance for planning under uncertainty. It also provides a means to better integrate non-lethal effects, whose timelines and interactions are difficult to assess through linear models but can be explored through structured, decision-centric scenarios.

Wargaming is not a substitute for operational experience, nor should it be treated as predictive. Its value is insight generation: exposing trade-offs, cascading effects, and adversary adaptation before they appear in conflict. Embedded properly, it becomes a normal part of NATO's targeting practice, complementing modelling and simulation, exercises, and real-world learning to improve decision-making in increasingly complex environments. ●

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Optimising Skill Acquisition in Military Aviation

The Effective Pilot Training Framework

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By Sébastien Lozé, FRA Air and Space Force Civilian Reserve

By Dr Sami Mecheri, FRA Armed Forces Biomedical Research Institute

CSAR mission departure. A complex operation requiring detailed planning and close coordination both in flight and on the ground.

Introduction

Training is the cornerstone of operational capability and the essential driver of skill development in aviation. However, a fundamental question remains: how should training be designed and organised to most efficiently unlock the potential of individual pilots? This question lies at the core of instructor concerns and is driving a wave of modernisation across NATO. Faced with pilot shortages and the need to expedite

readiness, nations are duty-bound to explore ways to reimagine training methodologies.

Several initiatives are already underway to maximise the effectiveness of instructional programmes. For example, the US Army's Aviator Training Next programme focuses on integrating virtual reality (VR) technologies, using headsets and physical flight controls, to deliver innovative instruction.¹ Similarly, the US Navy's Project Avenger (Naval Aviation Training Next)



Fire support is a highly complex mission that requires specific training design to ensure effective skill transfer to operational environments.

is shifting away from a rigid 'one-size-fits-all' approach toward competency-based learning, where event difficulty is individually tailored to maintain a constantly challenging environment.²

Collectively, these efforts pursue three important objectives:

- addressing pilot shortages by leveraging emerging technologies;
- expediting early training to gain more flight time in advanced airframes;
- increasing the throughput of aviators to minimise wait times between instructional phases.

While various initiatives address initial qualification training, the approach to training Instructor Pilots (IPs) often lags behind. IPs are not systematically provided with guidance on how to implement new methodologies and enhance pilot development. For instance, while studies provide insights into the optimal ratio of VR hours to live flight hours, they rarely offer guidance on the instructional dynamics required to maximise that time. In other high-stakes domains, such as elite sports or medical surgery, coaches and instructors are routinely guided on how to facilitate effective training through the application of skill acquisition principles.^{3, 4}

Currently, this level of support is largely absent in military aviation. This gap forces IPs to rely heavily on tradition, organising training in the same way previous generations did. While tradition has its merits, relying on it uncritically can exclude innovations based on empirical evidence. Skill acquisition is complex. Without clear, evidence-based principles, deciding how to introduce new skills or reinforce existing ones can be taxing and confusing.

In this two-part series, we introduce a framework for advancing skill acquisition in military aviation by translating principles from the science of skill to the aeronautical domain. This framework, named Effective Pilot Training, aims to provide aviation practitioners with evidence-based guidelines to support the translation of theory into practical training strategies. In the first part, we discuss key concepts for designing effective training and establish the framework. The second article will address how to integrate the framework into applied instructional practice.

Providing Clarity for the Instructor Pilot: Foundational Principles of Skill Acquisition

Success in the air depends on a pilot's ability to develop a specific set of perceptual, cognitive, and motor skills.

In this context, 'skill' encompasses more than the physical handling of the aircraft; it requires effective problem-solving and functional interaction with the operational environment. To optimise this process, IPs must understand the mechanics of how pilots develop such skills, from basic aircraft handling to tactical and complex qualifications. The following concepts form the basis of the Effective Pilot Training framework.

Learning versus Performance

An important finding in skill acquisition is the learning-performance paradox: performance during a single training session does not necessarily reflect how much retention, or learning, has occurred. Performance is transient and observable. It is the immediate result of the psychological and physiological state of the trainee, the instructor's guidance and feedback, and the repetition of a specific task. IPs may fall into a 'face-value' trap, assuming that a smooth sortie today means the skill is secured for tomorrow.

Learning, by contrast, is a permanent change in capability. It can only be measured by changes in performance over time, once the temporary support of the instructor is removed and memory consolidation processes have taken effect. A trainee may perform poorly during a demanding session (showing low immediate performance) despite engaging in effective learning. Conversely, a trainee may perform perfectly in a less demanding session yet learn very little. This distinction between learning and performance is a central tenet of the Optimal Challenge Point model.⁵

Optimal Challenge Point

The 'Optimal Challenge Point' is the point at which training difficulty yields the most effective learning. The Optimal Challenge Point model highlights that the level of difficulty required for good training performance is not the same as that required for effective learning outcomes.⁶ As illustrated in Figure 1, as training difficulty increases, performance naturally declines. However, the learning benefit actually increases up to a specific Optimal Challenge Point. Beyond this peak, difficulty exceeds the pilot's cognitive capacity, and both performance and learning decline sharply.

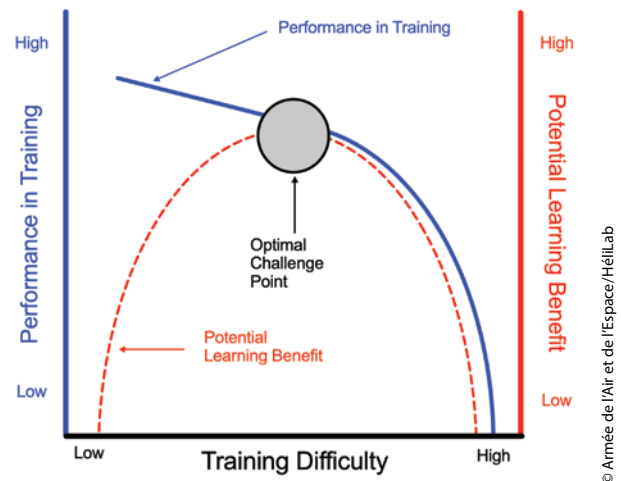


Figure 1: The inverse and non-linear relationship between training performance (solid line) and the learning benefit (dotted line) as a function of training difficulty (x-axis). This model illustrates how potential learning benefit during training relates to immediate performance and the Optimal Challenge Point for an individual pilot.

This model enables us to anticipate training outcomes. Training that is too easy results in high performance but low potential learning benefit. Training that is too demanding results in poor performance and decreased potential learning benefit. The IP's goal is to adjust parameters continuously to keep the pilot near that Optimal Challenge Point, prioritising durable learning over a clean grading sheet in the present.

Transfer of Training

'Transfer' describes how well performance gains from training situations carry over to untrained tasks, or to trained tasks under novel tactical scenarios. It is the ultimate return on investment (ROI) of training. Transfer can be categorised along a continuum, or broadly as either 'near' or 'far', depending on how closely the new scenario resembles the original training:

- Near Transfer: Trained skills apply to novel situations that remain highly similar to the training setting, for example, switchology or checklists.
- Far Transfer: Trained skills apply to complex, dynamic environments unlike the original training setting,



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NVG operations are among the most demanding missions. Effective training is essential for aircrew, enablers, and C2 elements to perform successfully in such environments.

for example, composite air operation (COMAO) or dynamic retasking.

The ultimate purpose of military operational training is to produce far-transfer effects, ensuring pilots acquire the ability to perform adaptively in contexts and scenarios they have never explicitly practised.

Training Specificity

Specificity is the degree to which training reflects mission demands. While a training environment may appear realistic at first glance, training specificity refers to replicating the underlying cognitive processes – the perception-action links, uncertainty, and time constraints of combat. If a pilot performs a skill in a sterile, predictable environment like a simulator, the specificity remains low, even if the simulator's dynamic flight model is accurate. To ensure knowledge retrieval and adaptive behaviour under fire, training must recreate demands found in operational sorties, as doing so favours the transfer of trained skills.

Introducing the Effective Pilot Training Framework

The Effective Pilot Training framework structures aviation practice around two critical dimensions – see Figure 2. The first is difficulty: the degree of challenge imposed on the pilot relative to current skill level. The second is specificity: the extent to which the training

environment faithfully replicates the demands of a combat mission.

The intersection of these two dimensions defines three distinct instructional approaches, each producing a different effect on pilot development:

- **Training-to-Learn:** Prioritising long-term acquisition over short-term performance.
- **Training-to-Maintain:** Reinforcing confidence and automaticity in existing skills.
- **Training-to-Transfer:** Replicating the friction of combat to ensure skills hold up under operational pressure.

As established in high-performance fields such as elite sports and surgical medicine, effective training requires more than just repetition; it requires targeted design.^{7,8} Differentiating training allows the IP to act not just as an evaluator, but as an architect of skill development. By deliberately manipulating the parameters of difficulty (challenge) and specificity (mission realism), IPs can purposefully design flying tasks and contexts to pursue three distinct instructional goals.

These goals are discussed according to the lifecycle of a military skill: acquiring it, maintaining it, and ultimately transferring it to the fight.

- 1. Training-to-Learn (Acquisition):** Training-to-Learn is the foundation. It aims to foster the acquisition of new skills by prioritising long-term retention over

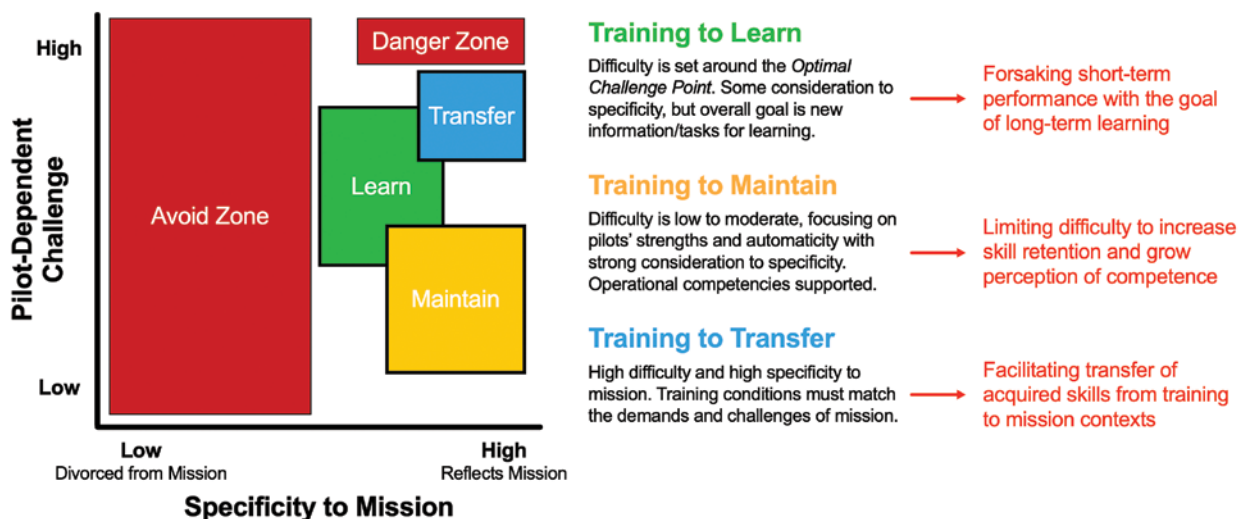


Figure 2: A training session can be positioned along two dimensions: the degree of training specificity (x-axis) and the level of training difficulty (y-axis). When the degree of specificity is low, training yields little transfer to mission contexts. It is therefore advisable to stay out of the 'avoid zone', regardless of whether the training difficulty is high (resulting in learning with minimal transfer) or low (resulting in no learning). At high levels of specificity, training is likely to produce good transfer of acquired skills to operational situations, allowing IPs to adjust the training difficulty according to instructional objectives. To foster learning, difficulty levels should be set to push pilots beyond their current capacity (*Optimal Challenge Point*), introducing new tasks and information into their flight environment to stimulate progress. To foster skill maintenance, difficulty should be moderate or low relative to the pilot's ability, but combined with a high degree of specificity. Finally, it is critical to avoid pairing very high difficulty with very high specificity ('danger zone') to prevent severe cognitive overload and flight training accidents.

short-term performance. To support this, IPs should place pilots at their *Optimal Challenge Point*. Because this zone compels the pilot to engage with new concepts, immediate performance may appear uneven or sub-optimal. The IP must accept this trade-off. This approach should underpin initial training, or any phase in which a pilot transitions to a new airframe or weapon system. Since the optimal level of difficulty is a moving target, the IP must continually adjust difficulty and specificity parameters to keep the pilot within this learning-focused zone, rather than allowing them to coast on easy successes.

2. Training-to-Maintain (Retention): Training-to-Maintain aims to sustain existing capabilities. Here, the goal is to develop automaticity and strengthen pilot confidence. The IP achieves this by maintaining high specificity (realistic cognitive demands and mission scenarios), while keeping difficulty moderate. This

allows the pilot to execute known procedures fluently in realistic contexts without being overwhelmed by failure. This type of training is crucial for reinforcing cognitive schemas in experienced pilots, or for rebuilding confidence in highly qualified aircrew returning from non-flying staff tours. It solidifies foundational skills before progressing to complex operations.

3. Training-to-Transfer (Mission Rehearsal): Training-to-Transfer represents the pinnacle of the framework. It fosters the application of acquired skills to the complexity of operational settings. Here, the IP utilises high levels of specificity and difficulty to reproduce the friction of combat faithfully. This training goal is critical in the work-up to deployment, such as Red Flag or Tactical Leadership Programme (TLP), where the objective is no longer teaching a skill, but facilitating its transfer to operational environments and ensuring it holds under pressure. Training design must create situations that compel



Air-to-Air Refuelling of two Caracals by an A400M Atlas assigned to special operational forces. This capability required pilots to develop advanced skills through a dedicated and targeted training programme.

the pilot to make split-second decisions based on all task-relevant information available in 'real missions' leading wingmen and unmanned systems, coordinating with special operations forces in evolving tactical situations, conducting risk assessment and management, and maintaining sound situational awareness. This is not merely practice; it is wartime rehearsal, conditioning the pilot's brain to recognise and react to the lethal cues of combat.

Conclusion

As NATO flight schools face increasing strategic pressure to raise throughput without compromising competency, the 'business-as-usual' approach to instruction is no longer sufficient. Modernising hardware, such as introducing VR, is only half the battle; training design must also modernise.

By integrating key principles of skill acquisition science into daily operations, the Effective Pilot Training framework provides IPs with reference points and the conceptual tools necessary to move beyond tradition. It empowers them to align every sortie with a specific developmental goal, whether

acquiring new skills (Training-to-Learn), cementing proficiency (Training-to-Maintain), or rehearsing for combat (Training-to-Transfer).

This framework is not limited to undergraduate pilot training; it can guide development across the full spectrum, from initial training students to Mission Commanders. In a forthcoming follow-up article, we will move from theory to practice, outlining how to operationalise this framework using advanced simulation, data analytics, and behavioural analysis to help deliver the next generation of combat aviators. ●

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Bridging NATO's Capability–Capacity Gap Through Commercial Effects

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Aircraft at March Air Reserve Base, California, a practical example of how commercial aviation can augment NATO Air Power capacity.

Introduction

Modern air forces face an operational dilemma. The demand for mission-critical effects, ranging from persistent Intelligence, Surveillance, and Reconnaissance (ISR) to Air-to-Air Refueling (AAR) and high-fidelity training, is expanding at a rate that outpaces the ability to generate, field, sustain, and modernise traditional organic assets. As acquisition cycles stretch into decades and unit costs rise, the ability of NATO nations to field sufficient capacity to meet dynamic capability demand has degraded. These capability and capacity shortfalls often stem not from technological stagnation, but from procurement and budgetary frameworks that struggle to match the pace of the modern threat environment.

To mitigate these shortfalls many NATO Allies are turning to the delivery of capabilities via an 'as-a-Service' (aaS) model. While commercially owned, commercially operated (COCO) contracted services have

been used by allied militaries for decades, the aaS model offered by some industry partners has advantages over the traditional procurement or contracting model. Rather than the traditional focus on platform ownership, where the military buys and maintains the assets and trains the crew, delivering capabilities as-a-Service allows defence organisations to procure specific operational outcomes on a subscription or on demand basis. Under this model, the 'effect' is the deliverable.

By shifting responsibility to certified commercial providers, NATO gains the flexibility to generate surge capacity through COCO services and scale its force structure in response to military needs, without sacrificing safety, security, and interoperability.

This article therefore argues that aaS should no longer be viewed merely as a stopgap for capability shortfalls, but as a deliberate strategic pillar of NATO force design to ensure resilience in high-intensity conflict.



US Navy F/A-18 refuelling over the Pacific Ocean, Summer 2022.

The Strategic Logic of as-a-Service

The current strategic environment has exposed a 'capability-capacity' gap in Alliance force structure. NATO must now simultaneously pursue high end capability gains while achieving numerically sufficient mass. To achieve these objectives within budget and time constraints, a new logic is required that shifts the focus from platform acquisition to effect delivery. The aaS model addresses three critical requirements for contemporary air power:

- **Operational Agility:** The model provides rapid access to specialised capabilities, bypassing the multi-year lead times of traditional procurement. It allows the immediate injection of surge capacity or the bridging of gaps while awaiting delivery of new sovereign platforms.
- **Resource Optimisation:** A subscription-based model transfers the burden of ownership, long term sustainment, and life cycle management to the commercial sector, allowing defence budgets to remain focused on high end frontline capabilities that do not currently fit within the aaS model, such as fighters or nuclear deterrence.
- **Mission Prioritisation:** By outsourcing enabling functions and infrastructure support to industry partners, military commanders can concentrate their organic

personnel and assets on core mission sets. This alleviates force design dilemmas where desired effects are constrained by military personnel quotas or limitations.

Air-to-Air Refuelling as-a-Service

Despite sustained modernisation efforts across European NATO tanker fleets, capacity shortfalls remain a persistent challenge. This is exacerbated by the increasing multi-role employment of modern tankers. When a platform like the A330 Multinational Multi-Role Tanker Transport (MRTT) is tasked with transport or medical evacuation, it is unavailable for its primary AAR mission. The resulting 'boom and hose' deficit impacts pilot currency, training readiness, and overall operational reach, a gap recognised within the NATO Defence Planning Process (NDPP).

The aaS model for AAR reduces operational burden on the end user, offering a flexible capacity in which commercial entities operate former military tanker aircraft. This model was successfully demonstrated during the Pacific Skies exercise in 2024, where commercial tankers successfully supported German Air Force Eurofighters on a 10-hour transit from Japan to Hawaii. This exercise validated the ability of non-organic assets to integrate into complex, long-range



AISR training flight over Continental United States (CONUS), Spring 2025.

deployments and adhere to the rigorous safety procedures required for transoceanic fighter drags.

Currently, most commercial AAR support is facilitated via bilateral Foreign Military Sales (FMS) cases or specific national contracts. However, to mature the COCO model within Europe, alternative frameworks are required. Establishing a multinational Support Partnership Agreement (SPA) through the NATO Support and Procurement Agency (NSPA) would allow coordinated tasking and a Direct Commercial Sale (DCS) arrangement. Such a construct provides the demand signal and contractual stability necessary for industry to invest in fleet availability, ensuring that commercial 'white tails' are ready whenever the military customer calls.

Airborne Intelligence, Surveillance, and Reconnaissance (AISR) as-a-Service

The demand for persistent, multi-domain situational awareness consistently outstrips national force structures. As Allied forces manage simultaneous requirements across multiple theatres globally, organic ISR fleets face high operational tempos and rising obsolescence. A significant inefficiency in current ISR employment is the use of military platforms for routine or enduring missions. This accelerates platform fatigue and reduces availability for crisis response.

Introducing complementary, non-organic AISR capacity acts as a force multiplier. By integrating commercially

operated solutions into existing Command and Control (C2) architecture, the Alliance can:

- Mitigate near-term capability gaps while waiting for future sovereign programs.
- Increase the modularity of force packages, swapping payloads electro optical/infrared (EO/IR) to synthetic-aperture radar (SAR) based on daily mission needs.
- Preserve high-end assets for contested environments where their survivability features are strictly necessary.

Commercial platforms, supported by expeditionary sustainment models, offer the sensor flexibility required to tailor effects to specific operational needs without the long-term overhead of a permanent fleet.

Expanding the Portfolio: Aerial Firefighting (AFF) as-a-Service

The increasing frequency and severity of wildfires globally have exposed the limitations of legacy aerial firefighting fleets. Many current platforms lack the speed, reach, and integrated technology required for modern wildfire suppression.

In Southern Europe, where seasonal pressures are most acute, authorities are increasingly evaluating COCO and government-owned, contractor-operated (GOCO) models as a means of enhancing climate resilience while relieving militaries of the burden of this task.



A 'FireSwift' AFF aircraft inbound to Fairford AFB to participate in RIAT 2025.

Modern commercial AFF solutions represent a generational leap beyond simple water drops. They integrate ISR sensors and Beyond-Line-of-Sight (BLOS) communications to provide real-time data to ground commanders, acting as a node within the emergency response network. These next-generation assets complement existing amphibious fleets, providing the short take-off and landing (STOL) performance required to operate from a wider range of airfields, thereby reducing response times during initial crisis phases. Additionally, the 'dual use' nature of these platforms creates interesting opportunities for a new aaS contract model. The same asset used for firefighting in the summer might be re-tasked for logistics or surveillance missions in the winter, maximising aircraft flexibility.

Space-as-a-Service: The High Ground of Commercial Integration

Nowhere is the velocity of commercial innovation more apparent than in the Space Domain. In February 2025, Allied Defence Ministers endorsed the first NATO Commercial Space Strategy, formalising the integration of commercial space capabilities into the Alliance's defence posture. This strategy recognises that the commercial sector is now the primary driver of innovation in orbit, particularly in relation to launch cadence and satellite proliferation.

The conflict in Ukraine demonstrated the decisive impact of commercial satellite communication (SATCOM)

in maintaining C2 when traditional infrastructure is degraded. NATO's strategy seeks to institutionalise this resilience through a 'disaggregated' architecture. By utilising multi-orbit constellations from commercial providers, the Alliance can create a network that is resilient against jamming and kinetic targeting.

Furthermore, commercial earth observation companies now provide 'unclassified but distinct' intelligence with high revisit rates. This allows NATO to monitor troop buildups and infrastructure changes without revealing sensitive national technical means (NTM). The ability to share this unclassified commercial data rapidly with non-NATO partners and the public is a crucial capability for countering disinformation in the 'grey zone' of pre-conflict competition.

Challenges and Frameworks: The 'Sovereignty Gap'

While the benefits of aaS are clear, reliance on commercial actors introduces new variables which must be addressed. aaS contracts need to include robust 'assured access' clauses and clear definitions of government direction during conflict. The NSPA play a critical role here. By aggregating demand across multiple nations – as seen in the Multinational MRTT Fleet (MMF) and Strategic Airlift International Solution (SALIS) programs) – NSPA creates the 'market mass' necessary to incentivise commercial providers to accept these rigorous terms.

Furthermore, legal harmonisation is required regarding the status of commercial providers in armed conflict. NATO must advocate for clear doctrines on indemnification and status protections to ensure that commercial partners can deploy forward with legal certainty. The shift must be from a transactional vendor relationship to a fully integrated partnership where the commercial provider is a stakeholder in the mission's success.

Conclusion

Delivering more military capabilities through the aaS model is a strategy for augmentation, not

replacement. It provides a flexible mechanism to increase capacity to support training and operations from peacetime through to crises. By utilising a subscription-based or pay-per-use model, responsibility for technological refreshment and operational currency shifts to the commercial provider, ensuring the Alliance benefits from the speed of commercial innovation.

As strategic competition intensifies, the ability to rapidly integrate commercial effects, spanning from AAR to Space, will be essential for maintaining a resilient and adaptable air power posture. The future force will not be measured solely by the assets it owns, but by the effects it can command. ●



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Conference Proceedings 2025

Disrupting Dominance – The Future of Air Superiority?

Introduction

In early October 2025, the city of Essen, Germany, became a hub of strategic debate and forward thinking as the JAPCC Joint Air and Space Power Conference brought together senior military leaders, policymakers, industry pioneers, and academics from across the Alliance. Under the theme '*Disrupting Dominance: The Future of Air Superiority?*' the event tackled one of the most pressing questions facing NATO

today: how to maintain control of the skies in an era defined by rapid technological change and shifting geopolitical realities.

Across two days of discussion and debate, participants examined how emerging technologies, lessons from recent conflicts, and new operational concepts are reshaping NATO's approach to deterrence and defence in the Air and Space domain. The conference offered not only a glimpse into the future of Air and



NATO Secretary General Mark Rutte delivers his video welcome address to this year's JAPCC Joint Air and Space Power Conference in Essen, Germany.

Space Power, but also a candid assessment of the challenges and opportunities that lie ahead. The following sections highlight the key themes, ideas, and insights that emerged from this year's discussions in Essen.

Disrupting Dominance: Imperatives from the 2025 JAPCC Conference

The security landscape is shifting with unprecedented speed, and with it, the very foundations of NATO's long-held air and space dominance are cracking. This was the unambiguous message at the heart of the 2025 Joint Air and Space Power Conference. In a fitting commemoration of the 20th anniversary of the Joint Air Power Competence Centre (JAPCC), the event convened a formidable cross-section of military leaders, policymakers, academics, and industry innovators. Gathered under the sobering theme 'Disrupting Dominance: The Future of Air Superiority?' the discussions were not hypothetical explorations of a distant future, but urgent examinations of a dangerous present. The conference's move to a larger venue – set to

run concurrently with the Euro Defence Expo (EUDEX) in 2026; it is a physical manifestation of the growing relevance and urgency of its mission.

A sobering recognition echoed throughout the two-day event: the traditional superiority enjoyed by NATO Air and Space Power is being actively, creatively, and effectively challenged. To prevail in this new era, the Alliance requires far more than just incremental technological upgrades; it demands a profound, and at times uncomfortable, cultural and doctrinal transformation.

The Strategic Imperative: Adapt or Cede Dominance

Opening keynotes established a clear strategic imperative with a palpable sense of urgency: NATO must fundamentally re-engineer its systems, doctrine, and culture. The era of assuming air superiority as a birthright is over, demanding a decisive return to proactive air defence fundamentals. This is not a mere shift in terminology from the relative comfort of 'air policing' to the harsh reality of 'air defence'; it is a critical, existential change in mindset.

NATO's air superiority is being squeezed from two directions in a dual disruption. First, the proliferation of low-cost, high-volume threats like one-way attack drones has democratised air power, effectively lowering the barrier to entry for state and non-state actors alike. This forces a difficult and often unsustainable cost-calculus on high-end platforms, where a multi-million-dollar missile may be the only answer to a few thousand-dollar threat. Second, peer competitors are rapidly fielding sixth-generation fighters and sophisticated autonomous systems, relentlessly closing the West's technological and quantitative gap. In this new reality, 'systems' refer not to individual platforms but to the deeply interconnected webs of sensors, shooters, and data that define modern multi-domain operations.

To secure the future, reform must be swift and decisive. The Alliance needs innovation structures that move at the speed of technology, not at the pace of bureaucracy. Technology must serve strategy, challenging old assumptions about both offence and defence – the ability to not only intercept the incoming missile, the proverbial 'arrow,' but to possess the reach, resilience, and resolve to 'strike the archer'.

Panel 1: Dominance Disrupted – Hard Truths and Urgent Realities

A candid examination of NATO's internal friction revealed a persistent and dangerous institutional resistance to innovation. Despite the availability of disruptive technologies, a risk-averse culture, often paralyzed by process, slows adaptation to a crawl. The panel stressed that fostering innovation must be a leadership priority, driven by a willingness to experiment, underwrite failure, and accept calculated risks.

This internal challenge is compounded by external pressures. The traditional reliance on US air power as a backstop is no longer a given, especially with the plausible rise of concurrent global crises that would stretch assets thin. Some nations, for instance, are heavily producing fighter aircraft in large numbers, rapidly scaling their capabilities and, crucially, narrowing the quality

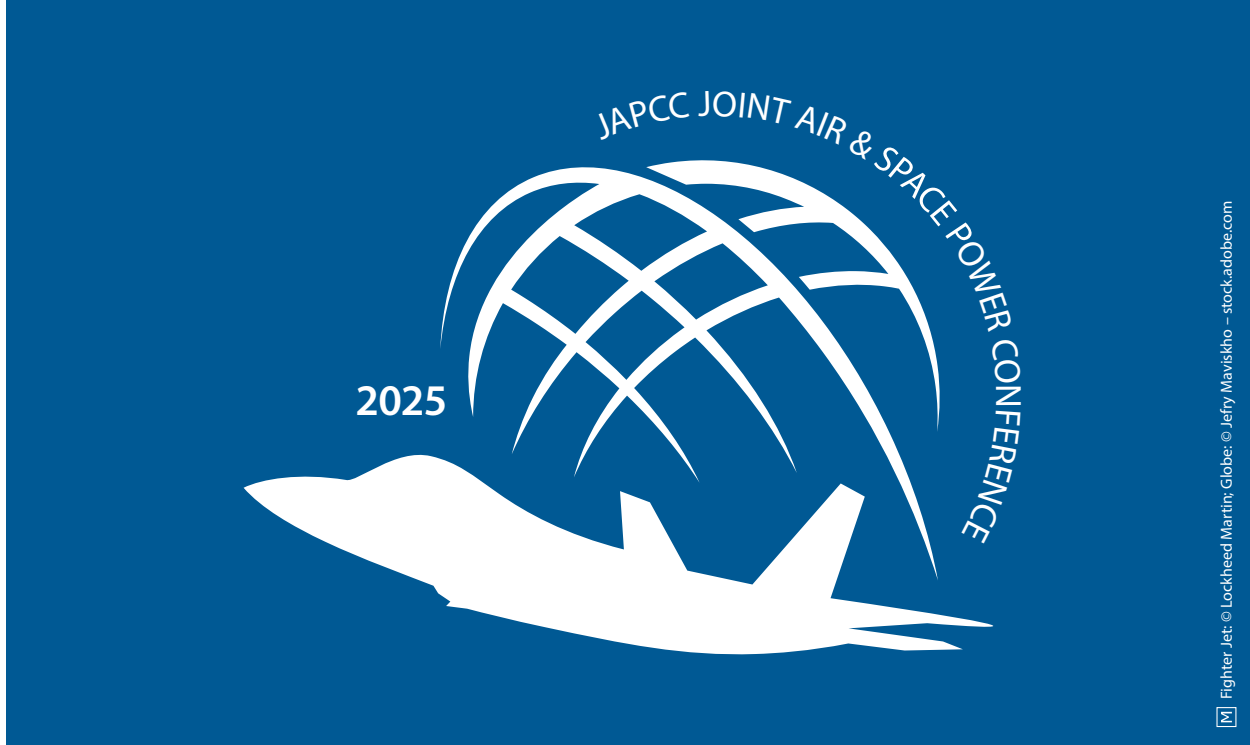
gap in pilot training and operational tempo. European nations must prepare for scenarios where they may have to act with far greater independence and operational resilience.

Perhaps the most visceral warning concerned the critical shortage of munitions across NATO. The most advanced aircraft in the world are rendered little more than expensive parade pieces without adequate stockpiles of high-end munitions, yet production rates remain dangerously slow. This isn't just a logistical problem; it is a strategic vulnerability of the highest order. The consensus was clear: increasing munition production and diversifying supply chains is more urgent than acquiring new platforms. The lessons from Ukraine underscore this reality, demonstrating that while legacy platforms can remain remarkably relevant with imaginative employment, air superiority remains the essential, non-negotiable enabler for freedom of manoeuvre in all domains.

Panel 2: The Tech Horizon – Integrating Mind, Machine, and Morality

The tactical and strategic landscape is being reshaped by advanced stealth, hypersonic weapons, and AI-driven autonomous systems. The proliferation of small drones was aptly likened to quantum physics versus traditional air power's Newtonian physics – each operates with its own distinct rules, scales, and contexts, defying a single unified theory of employment or defence.

Amid this technological surge, the human dimension remains central. Ethical clarity was powerfully framed not as a constraint but as a combat enabler, asserting that a morally confident force holds a distinct and durable advantage. The profound psychological burdens of remote warfare on operators, facing life-and-death decisions from thousands of miles away, highlight the critical need for robust support systems and a leadership culture that openly addresses moral injury. While AI can enhance decision-making and reduce cognitive load, its current struggles with ambiguity and deception mean human oversight is non-negotiable.



Autonomy must be constrained by clear, understandable operational boundaries to prevent catastrophic, unintended consequences.

As defence systems become fully digitised, intellectual property and data security morph into strategic, frontline assets. Collaboration with industry must balance the need for rapid innovation against the pervasive and persistent threat of economic espionage and state-sponsored cyber-attacks.

Panel 3: Reshaping NATO's Innovation Cycles – From Bureaucracy to Battlefield Velocity

Innovation is no longer a pre-conflict luxury; it is a core, continuous warfighting function. The war in Ukraine has unequivocally proven that innovation cycles must shrink from years to weeks, with solutions often prototyped and driven directly from the needs of the front lines. The panel's mantra was clear and unforgettable: '80% on time is better than 100% too late.' This requires a radical cultural shift away from rigid, 'gold-plated' requirements and toward functional, adaptable, and interoperable solutions.

This agility is fundamentally a sociotechnical challenge. New technologies are useless without updated doctrine, modernised training, and flexible operational

concepts to absorb them into the force. Innovation flourishes not from top-down directives but from informal, horizontal partnerships that connect military operators with engineers, academics, and small-to-medium enterprises.

Beyond accelerating its own innovation, NATO was urged to actively disrupt the cycles of its adversaries. This means aggressively protecting supply chains, securing intellectual property, and ending research collaborations that inadvertently benefit hostile actors. Autocratic regimes, despite their ability to mobilise their economies for war, are often hampered by rigid hierarchies and a deep-seated lack of trust in their personnel. NATO's enduring advantage lies in its educated, empowered people and its dynamic private sector. Modernising logistics and procurement is critical to leveraging this advantage, embracing modular systems and off-the-shelf solutions to deliver capabilities faster.

Panel 4: The Next Ten Years – Forging a Future-Ready Force

Looking ahead, the conference affirmed that conventional air power remains central to NATO's deterrence, but it must evolve significantly. Legacy systems require continuous modernisation to remain credible against

high-end threats, while distributed Command and Control (C2) must be perfected to function in a hyper-connected, degraded, and contested battlespace.

The future of warfare is unequivocally multi-domain. Seamless integration across Air, Land, Sea, Cyber, and Space is no longer aspirational but essential for survival and success. This demands robust, resilient digital backbones and flexible command structures that can synchronise cross-domain effects in real time.

This operational shift must be supported by a whole-of-society approach to defence. Industrial readiness, resilient civilian infrastructure, and public awareness are now strategic imperatives. Citizens must understand the nature of modern threats and be prepared to contribute to national resilience. This extends into the cognitive domain, where disinformation and psychological operations constantly seek to erode morale, sow division, and undermine trust in our institutions. Proactive, transparent strategic communication is NATO's primary defence against cognitive warfare, reinforcing the will to fight that ultimately underpins all military capability.

Conclusion: The Time for Action is Now

The 2025 JAPCC Conference delivered a powerful, unambiguous call for urgency. As one presenter stated, 'We must innovate quickly AND with our brains connected'. The challenges of the next decade – hybrid warfare, technological disruption, and relentless peer competition – are already here. NATO must accelerate its evolution, embracing distributed C2, deep multi-domain integration, and agile collaboration with industry.

Cohesion must be re-engineered through deliberate interoperability, shared doctrine, and a renewed commitment to collective defence. Equally vital is the human dimension: fostering the resilience of our people, communicating strategically with our populations, and strengthening the collective will to defend democratic values. The challenge is clear and monumental: to adapt not only our tools but our thinking, our institutions, and our culture. The time for comfortable deliberation is over; the time for decisive, unified action is now. ●



Keynote speaker General Seán Clancy, Chair of the EU Military Committee, takes questions from the audience following his address at this year's Joint Air and Space Power Annual Conference in Essen.

12th JASPN Air and Space Power Networking Meeting

From Shared Vision to Real Capability

The 12th Joint Air and Space Power Networking (JASPN) meeting gathered NATO experts in Kalkar from 12 to 13 November for focused discussions on strengthening cooperation, sharing operational insight, and accelerating capability development across the Alliance. As conflict continues in Ukraine and instability rises in the Middle East, the meeting underscored the need for rapid adaptation in an increasingly contested strategic environment. Colonel Vito Cracas, JAPCC Assistant Director, stressed that informed collaboration and shared understanding remain fundamental to NATO's strategic advantage. Building on foundations laid in 2024, JASPN 2025 focused on modernisation, agility, and the technologies shaping tomorrow's operational edge, turning collective thinking into practical and deliverable capability outcomes.

Digital Transformation & Autonomous Systems

Commandant Peter Vanderostyne highlighted the evolution of Tactical Data Links from supportive tools to strategic enablers within NATO's wider operational architecture. Despite remaining interoperability gaps, modernisation efforts, including Link 22 migration, crypto upgrades, and AI-supported networking, will underpin NATO's future Digital Backbone and enhance cross-domain connectivity. Complementing this, Colonel William Barksdale outlined the emerging Capstone Concept for Autonomous Collaborative Platforms to address peer competition and operational complexity. Six Lines of Effort, from human-machine teaming to ethical governance frameworks, ensure responsibility and oversight are embedded from the outset. Furthermore, Major Lucas Stensberg introduced the JAPCC AI Handbook, using a live demonstration of

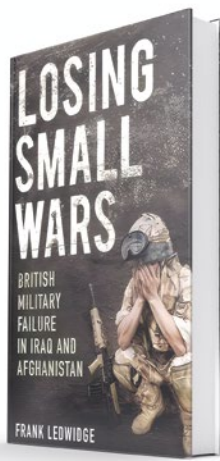
an AI recognition tool to illustrate both the operational potential and the need for careful management of emerging technologies.

Operational Agility & Strategic Synergy

Lieutenant Colonel Francesco Facchi explained how Agile Combat Employment enhances survivability through dispersed basing and flexible force posture, while Aircraft Cross Servicing, enabled by STANAG 3430, allows allied nations to regenerate air power more rapidly and efficiently. These concepts will be tested in exercises such as Pitch Black 26 to validate procedures and improve readiness. This operational shift is supported by Strategic Civil-Military Synergy: NATO Headquarters and Command and Control COE provided updates on AirC2 modernisation efforts, while EUROCONTROL addressed the impact of Global Navigation Satellite System interference on European airspace and its operational implications. Additional progress was reported by NATO SACT Staff Element Europe on long-term capability planning, the NATO Space COE on doctrine and education initiatives, and the European Air Transport Command on improving efficiency in international cooperation within the transport field.

Challenges as Drivers of Innovation

Personnel shortages, legal gaps, and interoperability challenges persist across the Alliance, yet JASPN 2025 demonstrated these pressures are catalysts rather than constraints. As Colonel Cracas concluded, the forum continues to unite the right expertise to strengthen collective capability and sustain operational advantage. ●



Losing Small Wars: British Military Failure in Iraq and Afghanistan

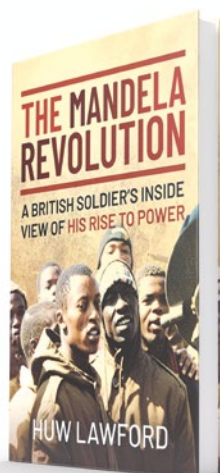
Frank Ledwidge provides a sobering autopsy of British military intervention in the 21st century. Drawing on personal experience and interviews with senior leadership, Ledwidge argues that the UK's failure in Iraq and Afghanistan was not a lack of tactical bravery, but a catastrophic vacuum in strategic thinking.

Of particular interest to the JAPCC reader is the author's analysis of 'institutional inertia'. He contends that the British military remained wedded to a 'Northern Ireland template' that was wholly inadequate for the multi-domain complexities of the Middle East.

Ledwidge is most scathing when discussing the 'post-conflict' phase; he illustrates how the absence of a viable political-military end-state rendered even the most successful kinetic operations moot. For airpower practitioners, this serves as a critical reminder: without a clear plan for the 'day after', air superiority is merely a bridge to nowhere. A must-read for those involved in Joint planning. ●

By Frank Ledwidge; Yale University Press, 2011

Reviewed by Lieutenant Colonel John van den Hudding, RNLASF, JAPCC



The Mandela Revolution: A British Soldier's Inside View of His Rise To Power

The Mandela Revolution provides a personal eyewitness account of South Africa's peaceful post-apartheid transition, told through the eyes of a British soldier involved in one of the most sensitive reforms of the new democratic state. Rather than a biography of Mandela or a general political history, Huw Lawford concentrates on the politically driven transformation of South Africa's armed forces following Mandela's election.

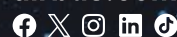
Central to the book is Lawford's account of supporting the integration of statutory and non-statutory forces into the new South African National Defence Force. His narrative offers a rare insider's perspective on a process driven more by political necessity than military logic, highlighting the complex interplay of security, politics, and reconciliation in a post-conflict society.

What sets The Mandela Revolution apart is its ground-level insight into institutional change under intense political pressure. Lawford frames his experience within reflections on post-apartheid governance and the influence of external actors, offering a focused contribution to civil-military relations and post-conflict transformation in Africa. Its relevance extends beyond history: contemporary armed forces face similar challenges in integrating and legitimising new recruits. In this way, Lawford's account serves not only as a historical case study and timely reflection on enduring challenges in military transformation amid profound political change. ●

By Huw Lawford; Pen and Sword Military, 2022

Reviewed by Obergefreiter Marietta Olschowy, DEU AF, JAPCC

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