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Autonomous Collaborative Platforms

A Strategic Roadmap for Allied Air Power

Joint Air Power Competence Centre

www.japcc.org

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From:

The Director of the Joint Air Power Competence Centre (JAPCC)

Subject:

Autonomous Collaborative Platforms – A Strategic Roadmap for Allied Air Power

Distribution:

All NATO Organisations – Releasable to the Public

Autonomous Collaborative Platforms (ACP) represent a transformative development in NATO's air power evolution, offering new opportunities to enhance Allied Air Command's contribution to Multi-Domain Operations (MDO). In recognition of this potential, the JAPCC has developed this strategic roadmap to provide NATO and its related entities with a shared, forward-looking understanding of ACP's strategic relevance and operational applicability as an emerging air-based capability.

The document is intended to inform, not direct, subsequent work. It situates ACP within NATO's broader transformation agenda, identifying Lines of Effort that can be pursued by organisations with the requisite expertise. These Lines of Effort are designed to support institutional readiness, foster coherence, and enable sustained coordination. Their dual purpose is to assess ACP's relevance and to prepare for potential integration into Alliance air power when they are deemed operationally viable.

By clarifying the conceptual landscape and outlining key areas for inquiry, this document provides a pathway for further analysis, dialogue, and coordinated exploration of ACP's strategic and operational implications across NATO and relevant partner entities. I encourage NATO organisations, Allies, and Partners to carry JAPCC's work forward and follow this strategic roadmap through to fruition.

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Table of Contents

Chapters

Annexes

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Executive Summary

The Strategic Imperative: NATO's historical reliance on high-value, exquisite, and numerically constrained crewed platforms is increasingly challenged by sophisticated Anti-Access/Area Denial (A2AD) networks. To maintain credible deterrence and operational freedom of manoeuvre in the future operating environment, the Alliance must shift towards a force structure that balances 'exquisite' capability with 'affordable mass' using a High-Low mix approach.

The Solution: Autonomous Collaborative Platforms (ACPs) are mission-autonomous aerial systems designed to team dynamically with human crews. They are defined not by their airframes, but by their ability to provide mission-level autonomy, modularity, and scalability. By integrating ACPs, NATO can:

- **Restore Mass:** Saturate adversary defences and sustain high-intensity operations through 'attritable' variants.
- **Expand Risk Tolerance:** Execute high-threat missions such as C-A2AD, Deep Precision Strike (DPS), Integrated Air and Missile Defence (IAMD) within adversary Integrated Air Defence Systems (IADS), without risking aircrew.
- **Achieve Cognitive Superiority:** Shorten kill chains via AI-enabled human-machine teaming.

The Roadmap: This document outlines six lines of effort (LOEs) to harmonise Allied development:

1. **Operational Innovation:** Codifying doctrine and tactics, techniques, and procedures (TTPs) for ACPs.
2. **Strategic Deterrence:** Using ACPs as a signal of resolve and regional posture.
3. **Force Design:** Integrating modular platforms into digital C2 architectures.
4. **Human-Machine Teaming:** Building trust through Joint Cognitive Systems (JCS).
5. **Industrial Resilience:** Leveraging modularity for mission flexibility and at-the-edge logistics.
6. **Governance and Ethics:** Ensuring responsible AI use and legal legitimacy.

Conclusion: ACPs are not merely a technological upgrade; they are a means of operationalising the NATO Warfighting Capstone Concept (NWCC). This strategic roadmap ensures the Alliance is conceptually and organisationally prepared to deter future conflict and, if deterrence fails, to fight tomorrow and win decisively.

Setting the Foundation for NATO's ACP Journey

This document sits at the beginning of NATO's ACP journey, not its end. It does not mandate procurement or prescribe force structure; it establishes the conceptual and analytical foundation from which doctrine, requirements, and acquisition decisions can follow. The Lines of Effort outlined herein define the preparatory work that must begin now, so that the Alliance is ready to fight tomorrow and fight together.

Introduction

The contemporary global security environment is characterised by an accelerating pace of technological advancement, and a resurgence of strategic competition among peer and near-peer actors. This dynamic nature necessitates that NATO continuously adapt its military capabilities to maintain credible deterrence and an effective defensive posture. Within this context, ACPs represent a transformative development in air warfare.

ACPs are a rapidly maturing class of autonomous aerial systems specifically designed to collaborate with airborne- or ground-based human crews. While they may share physical characteristics with drones, loitering munitions, or optionally crewed aircraft, ACPs are distinguished by their ability to operate with mission-level autonomy and collaborate actively and dynamically with crewed platforms in distributed force packages to execute both offensive and defensive missions. These systems are defined by function rather than form; equipped with onboard effectors and sensors, processing capabilities, and decision-making software, ACPs respond to real-time human inputs during mission execution while being capable of performing tactical-level mission tasks without continuous operator control.

ACPs encompass a broad spectrum of designs, ranging from simple, less costly, and potentially attritable systems to more exquisite, expensive, and survivable platforms, enabling tailored force packages aligned to diverse mission requirements. Design attributes like modular architectures, autonomous operation, and adaptable payloads enable ACPs to be integrated across varied operational contexts and adjusted as threat conditions and mission objectives evolve. Their modular design supports rapid and cost-effective payload changes, as well as incremental updates to both software and hardware, ensuring continued relevance over time. Complementary attributes, such as persistence, scalability, and a reduced logistical footprint further enhance their agility and responsiveness. As a result, ACPs offer enduring value across a wide range of mission sets and tasks, from strategic deterrence to humanitarian relief, supporting both combat and non-combat operations. Figure 1 illustrates various ACP types and roles based on broad mission categories (for illustrative purposes).

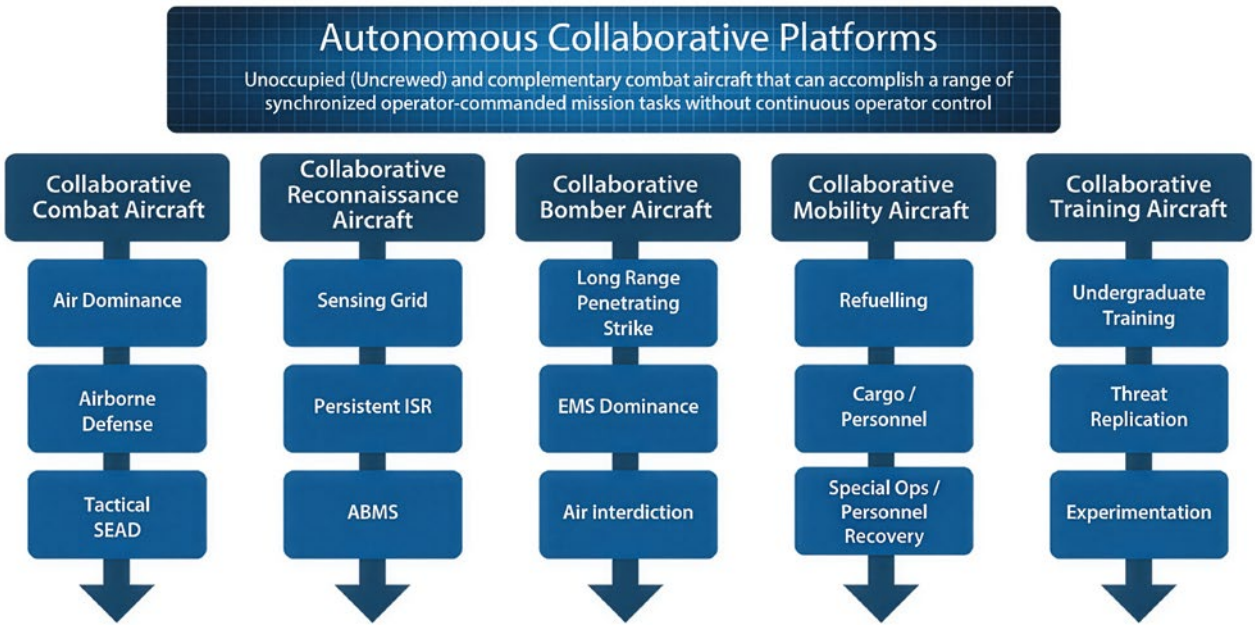

Figure 1: *ACP Types and Missions.*

In addition to their mission flexibility, ACPs offer the Alliance a means to add mass and resilience to their air forces. In a contested or combat environment, they can collaborate with crewed platforms as a system-of-systems for more flexible and robust response to complex threats. They show potential promise as intelligent, AI-enabled, dependable teammates capable of executing mission tasks with precision while maintaining alignment with the commander's intent. Like a human wingman, ACPs actively collaborate with a crewed counterpart, namely a custodial operator located in a crewed aircraft or an air- or ground-based command-and-control (C2) entity.

This teaming enhances package and mission capability, resilience, and decision-making through shared situational awareness and coordinated action. In short, human interface facilitates orchestration, ensuring ACPs apply sensors and effects appropriately throughout the mission.

ACPs should be understood not as a discrete technological advancement, but as a means of operationalising NATO's strategic guidance for future warfare. The NWCC articulates a long-term vision for transforming the Alliance's Military Instrument of Power (MIoP) to succeed in the 2040 operating environment. The NWCC emphasises cognitive superiority, layered resilience, influence and power projection, cross-domain command, and integrated multi-domain defence. Furthermore, the Concept for Deterrence and Defence of the Euro-Atlantic Area (DDA) translates this vision into an operational requirement for a more agile, resilient, and synchronised force structure. ACPs, through their autonomy, adaptability, and capacity for distributed operations, offer a practical mechanism to amplify mission effectiveness across various air and multi-domain missions, and are crucial to realising these strategic goals, directly supporting NATO's imperative to outpace and out-think adversaries in the future operating environment.

Baltic Defence Vignette (A2AD Penetration)

Deterrence has failed, and Russia initiates a major offensive against the Baltic States. AIRCOM's mission is unequivocal: establish and maintain pervasive air superiority across the region. However, Kaliningrad integrated A2AD architecture, developed over decades, presents a formidable challenge. Initial assessments indicate that addressing this challenge with crewed assets alone would risk high attrition rates for pilots and high-end platforms, degrading force generation capability for follow-on force packages and giving the adversary time to react, reconstitute, and disperse. NATO's Defence Planning Process anticipated this risk and invested in ACPs. Multiple ACP variants, optimised for sensing, electronic attack, suppression of enemy air defences, and precision strike, integrate seamlessly into the composite air operation (COMAO). Operating in concert with crewed fighters and C2 nodes, ACPs enable penetrating effects in the A2AD environment, leading to the degradation of Russian systems at scale. While ACP attrition rates are initially high, their employment allows the commander to tailor risk away from exquisite and crewed platforms, preserving high-value assets, and enabling follow-on efforts to control tempo and prevent NATO from being drawn into an attritional stalemate. Simultaneously, ACPs enable sustained air superiority deep into contested territory, reinforcing NATO's operational credibility and imposing greater cost on the adversary than it can inflict on friendly forces.

Scope of the Strategic Roadmap

This document establishes a strategic framework for the integration of ACPs into NATO's future force structure. It serves as a bridge between high-level strategic guidance, such as the NWCC, and the specific tactical developments required by individual nations.

Purpose and Limitations

- **Strategic Alignment:** This document provides a conceptual model to harmonise Allied efforts, ensuring that ACP development remains interoperable and aligned with Multi-Domain Operations (MDO).
- **Non-Prescriptive Nature:** This roadmap is descriptive, not directive. It does not mandate specific force structures or procurement paths for member nations.
- **Boundary Setting:** While it identifies the strategic potential of ACP, it does not provide specific Tactics, Techniques, and Procedures (TTPs) or technical architectures; those remain the purview of subsequent Operating Concepts (CONOPS/CONEMPs).

Application

The roadmap provided herein, driven by Lines of Effort (LOEs) and Imperatives, is intended for NATO staff elements and working groups to facilitate sustained coordination. The ultimate goal is to ensure that as ACPs technology matures, the Alliance is conceptually and organisationally prepared to maximise its operational impact with maximum interoperability.

Eastern Flank Alert Vignette (Distributed Sensing)

Russia's escalating incursions along NATO's eastern flank have driven the Alliance to a heightened alert posture. NATO AWACS, limited in mission generation by platform life, remain grounded due to critical parts shortages. In response, dispersed ACPs launch from multiple non-traditional forward locations. Leveraging their distributed sensing capabilities, ACPs augment ground-based sensors and restore a comprehensive air picture across the contested deep battlespace. As indications of imminent Geran-2 launches emerge, ACPs enhance the common operating picture (COP) providing seamless battlespace awareness to AIRCOM, and crewed alert aircraft for air defence. In this integrated approach, different ACPs equipped with onboard effectors engage hostile targets as authorised. The result: elimination of the Geran-2 threat — achieved without committing crewed fighters, preserving readiness and minimising cost per effect. Post-engagement, ACPs recover to dispersed sites where NATO members perform cross-servicing to refuel, rearm, and reconfigure platforms for the next mission, sustaining operational tempo and resilience in a contested environment.

Military Problem

The contemporary global security environment presents a dynamic and persistent challenge, manifesting along two major axes: the re-emergence of strategic competition with peer adversaries, and the enduring asymmetric threat posed by non-state terrorist organisations. The NWCC establishes that the Alliance's MIoP must be prepared to conduct future warfare against this full range of threats in a complex multi-region, multi-dimensional (physical, virtual, and cognitive) and multi-domain operating environment.

Peer competitors who have invested heavily in sophisticated, layered A2AD networks pose the predominant challenge faced by air domain forces. These networks create a highly contested environment that challenges NATO's fundamental freedom of manoeuvre and significantly increases the cost and risk associated with every air operation. The Alliance's existing air combat inventory comprises high-value, exquisite, and numerically constrained crewed platforms that are challenged to deliver the required effects at the necessary scale and persistence. This dynamic creates risk that inhibits sustained deep operations, constrains NATO's ability to shape, contest, and control the air domain, and exposes the following critical shortfalls in the Alliance's air domain inventory relative to the demands of high-intensity, multi-domain conflict:

- **Mass:** The quantity of available platforms and munitions is limited, hindering in-theatre persistence and the ability to saturate advanced defence systems.
- **Survivability:** Existing legacy platforms face reduced combat longevity and operational effectiveness when attempting to penetrate or operate within highly contested airspace.
- **Risk:** The concentration of crewed and exquisite platforms increases operational risk exposure which will likely constrain commander risk tolerance and limit operational flexibility to shape and fight within heavily contested environments.

Overcoming these shortfalls is critical for NATO to maintain credible deterrence and robust collective defence capability in potential future conflict with a peer adversary. ACPs can provide NATO members with a means to mitigate these shortfalls, while providing increased capacity and capability to contribute to missions in support of other NATO strategic core tasks: crisis prevention and management, and cooperative security.

GIUK Gap Vignette (Persistent Maritime ISR)

Russian naval activity intensifies in the Greenland-Iceland-United Kingdom (GIUK) Gap, placing sustained pressure on NATO's ability to maintain maritime domain awareness. Large geographic search areas and harsh climactic conditions challenge the P-8 fleet to its operational limits, resulting in crew readiness shortfalls and exposing a critical vulnerability in persistent maritime ISR coverage. To mitigate this limitation, ACPs launch from Alliance ships operating in the region. Their extended endurance and autonomous capabilities enable continuous surveillance networks alongside P-8 missions. By supplementing the P-8 fleet, as well as maritime and air C2 nodes, ACPs enhance the fidelity, persistence, and reach of the recognised maritime picture. The capability ensures maritime battlespace awareness, decision superiority, and crewed readiness, thereby reinforcing NATO's ability to deter and respond to adversary manoeuvres in the North Atlantic.

Central Idea

This strategic roadmap examines how a future force built around the characteristics of ACPs could fundamentally change the air domain calculus. ACPs offer a coherent and promising air-delivered solution; one that is survivable, adaptable, and available in sufficient quantity to operate at scale. Such systems offer a critical technological and conceptual path to help gain air superiority, enabling the Alliance to generate air power at the required scale and persistence.

A force structured around ACP characteristics offers a clear path to address the identified shortfalls of mass, survivability, and risk:

1. **Restore Air Domain Control:** ACP design and employment characteristics could enable the mass and risk necessary to saturate and dismantle sophisticated A2AD defences, creating dilemmas for the adversary and preserving the lethality of high-value crewed platforms. This directly supports the NWCC's imperative for Integrated Multi-Domain Defence.

2. **Advance Operational Agility:** With their inherent adaptability, scalability, and reduced logistical footprint, ACPs can ensure force relevance across all operational contexts. They can be utilised for decisive combat within highly contested environments, as well as for sustained, low-cost/low-risk ISR missions necessary for managing the persistent threat of non-state actors and terrorism.

3. **Expand Decision Space:** Through mission-level autonomy and dynamic teaming with crewed platforms, these systems have the potential to accelerate the decision-action cycle, contributing directly to the Cognitive Superiority and Cross-Domain Command requirements within the NWCC.

ACPs can enhance NATO's ability to shape, contest, and control the air domain. ACP design and capability attributes, including persistence, scalability, autonomous operations, and a reduced logistical footprint, offer distinct advantage in scenarios marked by elevated risk, limited infrastructure, or constrained logistics, where other platforms may be unavailable, cost-prohibitive, or operationally vulnerable. The inherent adaptability and modularity of ACPs provide senior leaders with credible options for controlling and operating the air domain at scale across the spectrum of conflict, extending their endurance and utility from high-intensity deterrence to other essential missions supporting crisis response, counterterrorism, disaster response, and humanitarian relief.

Grey Zone Deterrence Vignette (Hybrid Warfare Attribution)

Enduring hybrid warfare activities in the Baltic Sea continue to frustrate regional Allies, as attribution remains elusive using traditional ISR methods. Persistent widespread ISR coverage has historically been cost-prohibitive, allowing malign actors to operate with impunity and disrupt Alliance solidarity. ACPs operate at scale and at a fraction of traditional cost and manpower. Working in close coordination with frigates and the maritime air fleet, they extend ISR endurance, quality, and reach across the battlespace. When Russia's shadow fleet deploys anchors and drags them for several nautical miles, severing critical undersea cables, the act is captured in full-motion video. This evidence meets the threshold required to expose intent and strengthens NATO's ability to deter and respond within established legal and political collective defence frameworks. By delivering persistent surveillance and verifiable attribution, ACPs transform NATO's posture from reactive to proactive in the context of global competition, closing a critical gap in hybrid warfare deterrence and response.

Operational and Strategic Advantages

ACPs offer several explicit advantages to enhance NATO air power across operational and institutional dimensions:

Operational Advantages

Force Multiplication and Dilemma Creation

ACPs offer the potential to increase the quantity of sensors and effectors available to commanders, enabling the saturation of adversary defences, enhanced firepower, and the creation of complex strategic, operational, and tactical dilemmas that help offset existing numerical disadvantages.

Warfighting Capacity

Attritable ACP variants enhance combat sustainability through simplified, scalable, and cost-efficient production, enabling rapid replacement of losses, reduced logistical strain, and sustained operational tempo without overtaxing industrial capacity.

Force Enrichment, Not Replacement

ACPs offer the potential to enhance individual member nation force composition by complementing high-end crewed systems with persistent, lower-cost platforms. This improves adaptability across the full spectrum of conflict without displacing existing capabilities or undermining existing force investments.

Deep Effects

ACPs enhance NATO's ability to deliver operational effects deep within adversary territory by combining persistent reach with flexible delivery mechanisms that complicate and degrade adversary defensive systems.

Expanded Risk Envelope

Low-observable and attritable variants can be used to penetrate or saturate advanced A2AD systems and undertake high-risk missions, such as Suppression of Enemy Air Defences/Destruction of Enemy Air Defences (SEAD/DEAD) or operations in Chemical, Biological, Radiological and Nuclear (CBRN) conditions, without jeopardising highly trained personnel, thereby allowing commanders to operate within a broader risk tolerance envelope. As forward sensors, decoys, effectors, or EW platforms, ACPs offer to shape the battlespace and create windows of opportunity for other force elements to manoeuvre effectively, enhancing survivability for high-value, exquisite, and/or crewed platforms.

Accelerated Kill Chain Timelines

ACPs, when equipped with onboard AI and optimised for autonomous target recognition, can shorten Find, Fix, Track, Target, Engage, Assess (F2T2EA) cycles. Kill chains can be optimised using human-in-the-loop (HIL), or human-on-the-loop (HOL) constructs paired with networked effectors.

Extended Endurance and Persistent Presence

Unconstrained by human factors limitations, ACPs offer increased endurance, persistent presence, or uninterrupted range compared to crewed platforms.

Flexible Fielding and Launching

ACPs can be deployed without reliance on fixed airfields and runway infrastructure. This enables forward and dispersed operations, rapid repositioning, and increased survivability in contested environments.

Modular Design and Rapid Reconfiguration

ACPs can benefit from the cost savings of multi-mission airframe designs that use modular mission-payloads. Software-defined roles and plug-and-play payloads

allow for quick adaptation across ISR, strike, EW, and support functions without continuous acquisition cycles for hardware upgrades.

Strategic and Institutional Advantages

Cost-Efficient Through Scalable Design

Despite upfront investment, ACPs offer a structurally cost-effective means of augmenting force structure. Analysis suggests they can deliver ISR, strike, mobility, and support functions at a lower cost than traditional air power systems, enabling NATO to field greater numbers of combat and non-combat platforms and achieve 'affordable mass' without compromising flexibility or resilience.

Enhanced Deterrence

An ACP-enabled force is adaptable and scalable, complicating adversary assessments of Alliance force design and posture at any given time. This uncertainty creates planning dilemmas and increases the cost of malign action, thereby strengthening NATO's overall deterrence posture.

Catalyst for Allied Industrial Integration

With the appropriate standardisation and cooperation among Alliance members, ACP development provides a strategic catalyst for NATO industrial collaboration. Many current ACP concepts incorporate modular architecture, enabling a distributed production model in which national industries can contribute specialised subsystems, such as software, payloads, or airframes, rather than competing for entire platform contracts. Integration by design demands diligence, especially where design and manufacturing responsibilities are distributed across multiple Alliance nations. Adopting an open architecture ensures seamless integration across diverse fleets by avoiding national or proprietary vendor lock-in.

Regional Ownership and Alliance Strength

ACP modularity enables nations and industry to participate more readily, empowering European Allies to assume greater operational responsibility within the European theatre. This supports burden-sharing, strengthens regional readiness, and reinforces NATO's collective credibility.

Southeast Europe Vignette (Crisis & Mobility)

A series of catastrophic forest fires converge across Southeast Europe, devastating communities in an area that suffers from lack of access and responsive emergency relief. Communications infrastructure is destroyed, supplies dwindle, and affected nations urgently request NATO to lead the humanitarian response. Traditional airlift assets cannot land due to widespread damage and debris on the only operational airfield in the region. NATO deploys ACPs, capable of Vertical Take-off and Landing (VTOL) operations, to carry critical supplies to facilitate rapid runway repair. Guided by data from reconnaissance ACP surveying possible landing and drop zones, a mobility ACP identifies a viable location for VTOL landing. Critical cargo is offloaded and immediately distributed by land-based units, while other ACPs equipped with communication suites establish persistent connectivity. Their communication payloads reconnect local authorities to international relief agencies, restoring C2 of the operation. Meanwhile, the repair team fixes the runway rapidly, enabling traditional mobility assets to surge relief supplies and sustain recovery efforts.

Lines of Effort

The following Lines of Effort (LOEs) outline NWCC- and DDA-aligned pathways for advancing ACP integration and conceptual alignment within NATO. The LOEs do not mandate ACP adoption; they seek to foster conceptual clarity, align capability maturation, and inform senior leader decision-making. Each LOE includes Strategic Roadmap Imperatives that outline recommended actions to enable an interoperable and effective ACP capability, should member nations choose to procure them. These imperatives shape the conditions for transformation, reinforce multi-domain integration, and position NATO to act in a decisive and aligned manner. To highlight strategic relevance, each LOE identifies the NWCC Warfighting Development Imperative to which it contributes: Cognitive Superiority (CS), Layered Resilience (LR), Influence and Power Projection (IPP), Cross-Domain Command (CDC), and Integrated Multi-Domain Defence (IMDD).

1. Concept Development and Operational Innovation

Develop, test, harmonise, and refine the operational concepts, TTPs, and mission design frameworks necessary for effective autonomous and multi-domain combat employment – CS, IPP, LR, CDC, IMDD.

The integration of ACPs into NATO force design and operations requires a rigorous foundation of operational logic, tactical guidance, and institutional readiness. To support consistent and interoperable employment, ACP mission roles and teaming constructs must be conceptualised, tested, and formalised in doctrine. This foundation eventually enables nations to refine operating procedures and TTPs within the context of NATO exercises.

Central to this maturation is the preparation of the human element. Member nations must codify training to prepare operators, planners, and C2 nodes for dynamic teaming and autonomous mission execution. This effort should be supported by synthetic and Live, Virtual, Constructive (LVC) environments for scalable rehearsal and concept assessment. By refining ACP operational doctrine and systematically rehearsing it through NATO planning and training systems, this LOE strengthens the Alliance's ability to integrate ACPs into multi-domain operations with agility and strategic coherence.

The ultimate aim is to ensure that ACPs are effectively embedded as core contributors to tempo, flexibility, and survivability in MDO. This requires their seamless incorporation into NATO's C2 structures, planning cycles, and targeting processes, tailored to regional theatres and operational demands, including Agile Combat Employment (ACE) and dispersed operations.

2. Strategic Deterrence and Alliance Posture

Leverage ACP capabilities to enhance deterrence signalling, escalation management, and NATO's integrated force posture – IPP, IMDD.

To position ACPs as a credible contributor to NATO's deterrence posture, this LOE focuses on the strategic signalling value of autonomous employment. The unique attributes of ACPs, namely persistence, responsiveness, and risk management, present opportunities to reinforce NATO's deterrence logic through visible, scalable, and forward-operable demonstrations of resolve.

However, deterrence is not solely a matter of capability; it is a matter of perception, posture, and narrative. Therefore, this LOE emphasises the integration of ACPs into strategic messaging, posture planning, and multinational exercises designed to shape adversary calculations and reassure Allies. It is essential to outline how ACPs can signal readiness and cohesion across diverse theatres while remaining adaptable to evolving strategic contexts.

By embedding ACPs within NATO's deterrence architecture, the Alliance enhances its ability to project stability and manage escalation. This strategic positioning ensures that ACPs are recognised not just as tactical tools, but as an enduring component of NATO's strategic credibility in contested environments.

3. Force Design and Integration

Develop force structure, digital C2 architectures, and interoperability frameworks to integrate ACPs seamlessly across domains and national systems – IPP, LR, CDC.

ACPs can reinforce or fill operational gaps, including C-A2AD, IAMD, ISR, strike, mobility, and training, while remaining responsive to diverse operating conditions. Their modular, expendable, and autonomous nature challenges legacy Western air power assumptions about survivability, force structure, and unit value, prompting new approaches to scalable, integrative force design. For instance, modularity enables coherent employment across land, air, maritime, cyber, and space domains, serving as connective tissue between disparate capabilities and allowing tailored integration across alliance echelons and national force structures.

This, however, demands interoperability not only in technical terms but also in operational doctrine, digital architecture, and sovereign airspace integration, requiring adaptive deconfliction, comprehensive spectrum harmonisation to ensure resilience in denied or degraded electromagnetic spectrum (EMS) environments, and compliance with national regulatory frameworks. Furthermore, this LOE recognises that a software-defined force requires a sovereign-aware data architecture; one that enables the secure pooling of mission-essential data while respecting national sensitivities.

Expendability reshapes how risk, mass, and replenishment are factored into planning. Furthermore, autonomy-driven execution and teaming require flexible C2 models with interfaces that adjust to varying autonomy levels and support clearly defined authorities for machine-led operations. This requires an autonomy-aware doctrine to guide employment across domains, as well as a federated digital design to enable centralised command with distributed control. Finally, force design must account for the human capital shift, identifying the specialised 'digital force' of data and software specialists required to sustain these platforms. Through these efforts, ACPs will evolve beyond a nationally bounded asset into a shared, interoperable capability embedded within NATO's operational and digital ecosystem.

4. Human-Machine Teaming and Cognitive Integration

Advance NATO's human-machine teaming proficiency and decision support while leveraging the advantage of autonomy across domains – CS, CDC.

ACP contributions depend not only on technical performance, but on the quality of human-machine

teaming (HMT). This relationship must be anchored in trust, shared mental models, and adaptive decision-making, supported by effective cognitive and interface design. Whether ACPs assume roles such as wingman, scout, or effector, their behaviour must remain interpretable and aligned with mission intent, requiring structured teaming protocols that reflect this operational versatility.

Achieving effective HMT demands a cognitive architecture that enables fluid interaction, transparent reasoning, and mutual adaptability between humans and machines. Joint Cognitive Systems (JCS) principles provide a foundation for such interaction, while explainable AI and rigorous validation, verification, and accreditation (VV&A) processes help sustain operator confidence over time.

To maintain trust and operational coherence, ACP autonomous algorithms must also be subject to recurrent calibrations. This ensures continued alignment with evolving mission parameters, operator expectations, and contextual constraints. By establishing qualification standards and supporting architectures, NATO will ensure that ACPs integrate into multi-domain C2 workflows as trusted and agile teammates.

5. Industrial, Logistical, and Technological Resilience

Build an efficient and robust logistical, industrial, and digital capacity distributed across the Alliance that can produce, maintain, and sustain high-tempo ACP logistics at scale in contested environments – IPP, LR, IMDD.

ACPs will constitute a diverse class of modular systems heavily reliant on digital data link assurance, modular adaptability, and integration by design. A high operational tempo will place distinct demands on NATO's logistical, industrial, and digital systems. The logistical system must support attritable, expendable, and exquisite variants, each requiring tailored lifecycle strategies and differentiated sustainment approaches. High sortie rates, combined with distributed basing and contested operating environments, necessitate mobile, runway-independent launch and recovery options. To ensure sustained mass in high-intensity conflict, this LOE promotes the adoption of at-the-edge manufacturing and additive manufacturing capabilities, enabling forward-positioned maintenance and the rapid replacement of components in degraded logistical chains.

While modular architecture enables rapid reconfiguration, it demands agile supply chains and standardised, robust digital interfaces to support mission-specific adaptation and secure information exchange across domains. Beyond frontline sustainment, ACP development offers a unique opportunity to strengthen industrial collaboration across NATO. While the Alliance's need to integrate ACP physically and digitally with a wide range of national platforms encourages alignment, its modular architecture allows national industry to contribute subsystems, such as payloads, software modules, or airframes, rather than complete platforms.

This opens the door to subsystem-level participation, enabling flexible and resilient industry while fostering transatlantic burden-sharing. This LOE therefore ensures that ACPs are not only deployable and sustainable, but also serve as a catalyst for allied industrial integration, anchored in a logistics and production framework purpose-built for its operational profile. To realise this potential, NATO nations must collaborate to expand munitions production, accelerate replenishment pipelines, and align procurement pathways to support coalition-wide availability.

6. Governance, Ethics, and Legitimacy

Establish and/or influence the policy, legal, and ethical frameworks necessary to ensure responsible innovation, transparency, and public legitimacy for ACPs. This reinforces NATO's values-based approach and responsible use of emerging technologies – CS, IPP, CDC.

If NATO adopts ACPs as a shared autonomous capability, its roles, from ISR to kinetic effects, will raise distinct ethical, legal, and public legitimacy challenges. These concerns are not limited to the moment of

employment; they begin with how ACPs are developed, produced, and integrated across nations. As the Alliance explores modular approaches to capability generation, it must be prepared to confront questions of shared accountability and design authority.

Embedding ethical safeguards and legal clarity from the outset is essential to ensure that ACPs reflect NATO's Principles of Responsible AI Use (PRUs), including accountability, reliability, and human oversight. These foundations must be matched by transparent institutional communication, reinforcing public legitimacy and trust in ACP operational value and ethical posture.

This LOE ensures ACPs are not only technically sound but also ethically defensible and societally accepted. By aligning with NATO's values and international humanitarian law, this framework provides the necessary authority and responsibility to govern autonomous action, particularly in contested environments where human oversight must be balanced with machine-enabled speed.

Adversary Replication (Training)

Modern air combat training with fifth- and sixth-generation fighters demands adversary threat replication at a scale NATO's crewed fighter fleet cannot provide. Generating sufficient red-air sorties for live-fly exercises has become expensive and manpower-intensive, resulting in suboptimal training for advanced systems. This shortfall threatens NATO readiness and undermines preparation for high-end warfare. NATO addresses this gap by using ACPs as simulated aggressors. Informed by the latest intelligence on adversary tactics and capabilities, ACPs deliver realistic, adaptive adversary behaviour without the severe costs and logistical burden of crewed replication. Their ability to dynamically adjust tactics during engagements creates a training environment that mirrors the complexity of future air combat while preserving readiness and force structure. By integrating ACPs into advanced training scenarios, NATO ensures Alliance air forces maintain tactical credibility by preparing crews for the demands of next-generation warfare without compromising operational availability of the crewed fighter fleet.

Critical Capabilities

CC 1: ACP-informed concept development, training, and infrastructure assessment

NATO will require analysis and assessment mechanisms to develop, assess, and refine ACP-related concepts through experimentation. Defining ACP traits, namely modularity, expendability, and variant diversity, must inform concept logic, doctrinal development, and TTP design.

Subject matter experts require targeted training to align with NATO planning frameworks and reflect operational realities across mission sets, regions, and domains. This includes ACP integration into synthetic and LVC environments for scalable mission rehearsal and concept assessment. Without this foundation, NATO cannot evaluate ACP mission utility, ensure conceptual coherence across the conflict continuum, or support institutional learning through iterative refinement.

CC 2: ACP-based force package planning processes and C2 architecture

The Alliance requires integration of ACPs into its operational planning and C2 processes. This necessitates tailored toolsets capable of managing ACP-enabled force packages with scalable responsiveness, variant-aware tasking, and flexible reconfiguration.

These constructs must reflect the dynamic autonomy of ACPs and be designed to support shifting autonomy levels and machine-enabled decision-making. Without this transformation, NATO risks constraining ACPs within legacy C2 paradigms that are ill-suited to exploit their full operational potential.

CC 3: Theatre-specific strategic messaging supporting regional ACP postures

NATO requires a coordinated strategic messaging effort to integrate ACPs into Alliance posture planning and deterrence signalling. The persistent presence and risk-tolerant profiles of these systems offer new opportunities to shape adversary perceptions and reinforce Allied resolve. Messaging must reflect regionally grounded force postures and align with broader NATO objectives to ensure coherence between operational capability and the strategic narrative. A failure to harmonise messaging risks adversary miscalculation and may undermine the perceived unity of the Alliance.

CC 4: Interoperability standards for NATO-wide modular ACP design, production, employment, and servicing

The promise of ACPs — rapid iteration, scalable production, and seamless integration — depends on the robust implementation of interoperability standards. NATO requires the adaptation of standards that support modular design and servicing across national and industrial boundaries.

These standards must ensure that components and support structures operate cohesively across diverse technical ecosystems throughout the capability lifecycle. Without them, NATO risks a fragmented development landscape that undermines operational coherence and multinational scalability.

CC 5: Agile and scalable industrial, procurement, production, and logistics frameworks for ACPs

NATO requires agile frameworks for procurement, production, and logistics that support ACPs across their lifecycle. These systems must be capable of shifting rapidly from prototyping to mass output, utilising additive manufacturing and federated production to ensure resilience.

Logistics architectures must support forward servicing, rapid replacement, and autonomous recovery under contested conditions. Without such transformation, NATO risks slow adaptation and an inability to scale ACP-enabled operations to meet high-intensity mission demands.

CC 6: Interoperable interface designs actively and effectively supporting human-machine teaming and cognitive integration

NATO requires cognitive and procedural interface designs that support seamless integration between ACPs and crewed platforms. These interfaces must accommodate dynamic levels of autonomy in ways that support shared situational awareness and mutual trust.

This requires cognitive models that align machine reasoning with human intent, allowing for intuitive interaction and rapid comprehension in high-stress environments. Without these joint cognitive interfaces, the Alliance risks brittle coordination and reduced operational tempo in complex missions.

CC 7: Ethical and legal governance frameworks and mechanisms ensuring transparent and compliant ACP employment

The ethical and legal challenges of ACP employment are mission critical. NATO requires the ability to rigorously assess the implications of machine-assisted decision-making and ensure compliance across diverse legal regimes and operational contexts.

This requires robust governance frameworks that ensure ACPs are employed transparently and in accordance with International Humanitarian Law. Establishing these frameworks, referencing foundational works like the *JAPCC 2016 Legal and Ethical Implications* white paper, is essential to maintaining public legitimacy and Allied trust.

Annex A

ACP Strategic Roadmap Imperatives

The imperatives outlined in this annex support the potential adoption of ACPs into NATO's force structure. While not exhaustive, they provide a coherent and actionable foundation for implementation guidance and institutional alignment.

LOE 1: Concept Development and Operational Innovation

Imperative 1-A: Consider ACP-specific characteristics and constraints to develop concepts that accelerate operational tempo, support survivable and distributed operations, and extend tactical reach in contested environments.

Imperative 1-B: Codify ACP roles and behaviours into NATO doctrine and associated tactical guidance.

Imperative 1-C: Support institutional learning and adaptation through deliberate and iterative TTP refinement.

Imperative 1-D: Inform doctrinal development and guide long-term capability planning through continued strategic concept refinement.

Imperative 1-E: Align ACP employment logic with NATO's established strategic planning frameworks.

Imperative 1-F: Define ACP roles across C-A2AD, IAMD, ISR, strike, mobility, and training tailored to mission-specific and regional requirements such as Arctic endurance, Baltic saturation, and natural disasters.

Imperative 1-G: Ensure conceptual coherence across deterrence, crisis response, armed conflict, post-conflict stabilisation, and adaptive operational constructs such as escalation management and distributed operations.

Imperative 1-H: Continuously validate ACP roles and mission utility across the full conflict continuum in conjunction with other multi-domain assets.

Imperative 1-I: Develop ACP- and autonomy-aware C2 doctrine and decision frameworks.

Imperative 1-J: Establish ACP employment concepts tailored to ACE, dispersed basing, and forward-operable launch constructs.

Imperative 1-K: Incorporate ACPs into synthetic and LVC environments for scalable mission rehearsal, concept development, and validation.

Imperative 1-L: Develop ACP-integrated training programs for aircrew, planners, and C2 operators that reflect operational realities across mission sets and threat environments.

LOE 2: Strategic Deterrence and Alliance Posture

Imperative 2-A: Integrate ACPs into Alliance strategic messaging and posture planning.

Imperative 2-B: Demonstrate ACP capabilities through visible exercises and multinational deployments.

Imperative 2-C: Use ACP persistent presence, rapid responsiveness, and comparatively risk-tolerant profiles to signal resolve and readiness.

Imperative 2-D: Align ACP employment with NATO deterrence objectives in the European and other relevant Theatres of Operations.

LOE 3: Force Design and Integration

Imperative 3-A: Leverage modular ACP architecture to enable flexible and scalable capability development.

Imperative 3-B: Align ACP force design with national procurement pathways and agreed NATO capability targets.

Imperative 3-C: Ensure standardisation on the technical and mission levels to enable modular and whole-system connectivity and interoperability throughout NATO.

Imperative 3-D: Adopt Modular Open Systems Architecture (MOSA) and NATO STANAGs for interoperable ACP development.

Imperative 3-E: Integrate ACPs into national airspace systems to facilitate routine and permissive transit to and from exercise areas or employment zones.

Imperative 3-F: Develop ACP-specific force packages tailored to national and alliance priorities and based on validated operational requirements and mission effectiveness.

Imperative 3-G: Ensure ACP force structure supports both strategic deterrence and operational and tactical flexibility.

Imperative 3-H: Balance exquisite, attritable, and expendable ACP variants across defined capability tiers.

Imperative 3-I: Tailor ACP variants, variant selection, and implementation to regional requirements based on environmental, threat and basing considerations.

Imperative 3-J: Tailor ACP configurations to regional theatres and specific mission requirements.

Imperative 3-K: Tailor ACP variants, variant selection, and implementation to fulfil roles in C-A2AD, IAMD, ISR, strike, mobility, and training, ensuring relevance across the full spectrum of multi-domain NATO missions.

Imperative 3-L: Integrate ACPs into ATO/ACO cycles, joint targeting processes, and coalition tasking frameworks where appropriate based on validated operational requirements, to ensure coherence across multi-domain mission planning and tactical relevance alongside other multi-domain assets.

Imperative 3-M: Design scalable C2 interfaces for dynamic tasking, re-tasking, and real-time mission adaptation.

Imperative 3-N: Ensure ACP functionality under degraded, disrupted, or denied C2 conditions.

Imperative 3-O: Integrate ACPs into joint and coalition C2 networks to enable effective multi-domain coordination.

LOE 4: Human-Machine Teaming and Cognitive Integration

Imperative 4-A: Implement Joint Cognitive Systems (JCS) principles to support robust human-machine shared mental models and adaptive teaming.

Imperative 4-B: Build operator trust through transparent AI, explainable autonomy, and rigorous validation, verification, and accreditation (VV&A) processes, and ongoing (re-)calibration procedures.

Imperative 4-C: Train for dynamic teaming, cognitive load management, and machine-enabled decision-making in complex Manned-Unmanned Teaming (MUM-T) environments.

Imperative 4-D: Establish human-machine teaming protocols and associated qualification standards for human and machine mission roles (e.g., mission commander, package commander, wingman, scout, decoy, and effector).

LOE 5: Industrial, Logistical, and Technological Resilience

Imperative 5-A: Develop resilient, low-latency, secure Low Probability of Intercept/Low Probability of Detection (LPI/LPD)-capable data links for contested environments.

Imperative 5-B: Enable ACP-to-ACP and ACP-to-crewed platform collaboration across multinational and joint formations.

Imperative 5-C: Establish digital testbeds and LVC environments for Alliance-wide ACP experimentation and validation.

Imperative 5-D: Develop maintenance and lifecycle strategies for expendable, attritable, and exquisite ACP variants across their full service life.

Imperative 5-E: Enable rapid reconfiguration and mission-specific adaptation through standardised modular design.

Imperative 5-F: Expand munitions production and establish ACP replenishment pipelines capable of supporting sustained operations.

Imperative 5-G: Develop runway-independent launch and recovery concepts and systems and mobile sustainment systems.

Imperative 5-H: Align modular development with national capability portfolios and procurement pathways to ensure coherence and affordability.

Imperative 5-I: Foster transatlantic industrial participation to enhance regional resilience and equitable burden-sharing.

Imperative 5-J: Leverage modular ACP architecture to enable flexible and scalable capability design.

Imperative 5-K: Leverage modular ACP architecture by promoting distributed subsystem-level industrial contributions (e.g., payloads, software, airframes) across NATO to bind Alliance industries through shared development and integration initiatives.

LOE 6: Governance, Ethics, and Legitimacy

Imperative 6-A: Operationalise NATO's Principles of Responsible AI Use (PRUs) consistently in ACP development and employment.

Imperative 6-B: Define and enforce Meaningful Human Control (MHC) appropriate to mission context in lethal applications.

Imperative 6-C: Address public perception and proactive strategic communication regarding ACP use.

Imperative 6-D: Develop and coordinate Alliance-wide ethical and legal frameworks for responsibility and accountability to govern the modular development, production, integration, and use of ACPs, including machine-enabled autonomous decision-making.

Imperative 6-E: Define authority, responsibility, and applicable ROE for autonomous action in contested environments.

Annex B

Glossary

There are many terms used in this paper that are assumed to be well understood. This table is provided to give clarity to some specific terms.

Term	Definition
ACP(s)	Autonomous Collaborative Platform(s); aerial systems with mission-level autonomy designed for human-teaming.
Attritable	A platform designed for high-risk missions where its loss is professionally and financially acceptable, but it is not intended to be 'one-way'.
Expendable	Low-cost systems designed for single-use or 'one-way' mission profiles (e.g. loitering munitions).
Exquisite	High-end, highly survivable, and expensive platforms (crewed or uncrewed) typically produced in lower numbers.
HMT/MUM-T	Human-Machine Teaming/Manned-Unmanned Teaming; the coordinated employment of crewed and autonomous systems.
MOSA	Modular Open Systems Architecture; a technical framework that enables components to be swapped/upgraded regardless of the original manufacturer.
Mission-Level Autonomy	The ability of a system to perceive its environment and make decisions to achieve an objective without constant human 'joystick' control.

Notes

Notes

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