Transforming Joint Air and Space Power

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Joint Air Power Competence Centre


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Editorial

I am delighted to present the latest edition of the JAPCC Journal. This issue showcases a diverse collection of articles focussing on concepts important to NATO. But first, we must acknowledge the ongoing large-scale conflict in continental Europe, where Ukrainians continue to demonstrate unwavering resilience in the face of relentless Russian aggression. As the conflict enters its third year, the importance of NATO unity to ensure regional security cannot be overstated. In order to gain a comprehensive understanding of the current landscape, it is crucial to analyse developments from this conflict as well as emerging concepts and trends within the Alliance. In this journal, our esteemed authors draw upon their unique expertise and experiences to provide valuable insights into various relevant topics shaping the future of NATO.

We begin this issue with a captivating article by Major General Juha-Pekka Keränen, Commander of the Finnish Air Force. He introduces us to the robust capabilities that our new NATO member offers to the air domain. Following this, we expand our view to showcase how Allied Air Command tackles multi-domain operations as a functional component command. This piece melds the concepts of MDO with the Command's five priorities and offers astute interpretations of how to best synchronize the principles of MDO with military and non-military instruments of power. Next, we dive into the benefits and limitations of emerging and disruptive technologies, by examining practical applications for quantum technology. Following this, we examine possibilities for electrifying aviation. Moving on, the journal explores the future of airborne surveillance and C2 by leveraging a systems-of-systems approach to achieve Alliance Future Surveillance and Control.

We then continue with viewpoints from Allied Air Command on their lessons learned from the Ukraine crisis, and how the warfare transitioned into land engagements when air superiority was not achieved by either side. The next article provides an analysis of space launch capabilities with a proposed strategy of how a diversified and resilient space industry can help NATO achieve robust heavy space lift. We then shift focus back to emerging and disruptive technologies, specifically what artificial intelligence can bring to the fight through large language models focused on the air domain. The journal then concludes with highlights of the JAPCC's 2023 Conference, covering wide-ranging topics from space domain awareness to partnerships, logistics, interoperability, and much more.

Thank you for taking the time to explore this recently redesigned journal. I would like to express my sincerest gratitude to all of our contributing authors. Furthermore, our reader's valuable feedback is essential in helping us enhance and advance the discussion on the ***transformation of Joint Air and Space Power***. We encourage you to visit our website at www.japcc.org, follow us on LinkedIn or (Twitter) X, or email us at contact@japcc.org.

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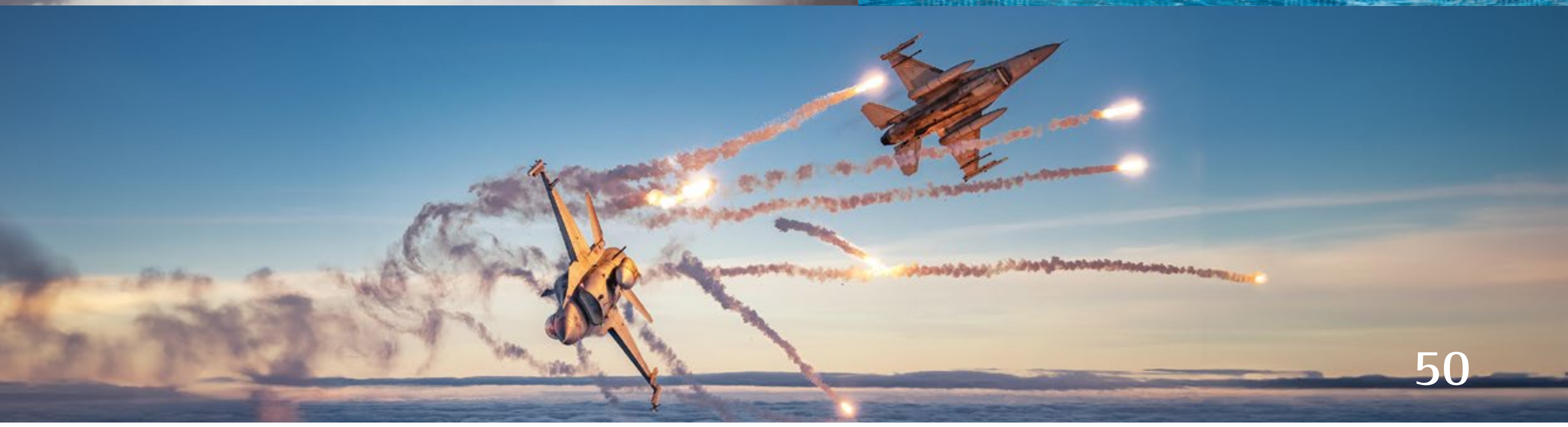

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Purpose
The JAPCC Journal aims to serve as a forum for the presentation and stimulation of innovative thinking about strategic, operational and tactical aspects of Joint Air and Space Power. These include capability development, concept and doctrine,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

Cover Photo: The Finnish Air Force F/A-18C/Ds (HN-408/HN-466) recently engaged in interoperability training with the United States Air Force F-35A Lightning II (20-5570) from the 48th Fighter Wing Lakenheath. This collaboration highlights Finland's decision to select the F-35 Lightning II as the successor to its Hornet fleet and the future cornerstone of its air force. The procurement of these advanced aircraft demonstrates Finland's dedication to bolstering its air force capabilities and enhancing its alignment with NATO forces.

‘Today and in the future, the FINAF has a crucial role in constituting the backbone of security in the challenging Northern Eastern operational environment.’

The Finnish Air Force

Ensuring Readiness and Leveraging High-End Air Capabilities while Integrating with NATO

By Major General Juha-Pekka Keränen, Commander of the Finnish Air Force

Introduction

The Finnish Air Force (FINAF) is recognized for its rich history, professionalism, capability, and commitment to securing and defending Finnish airspace, including the highest per capita ratio of fighter aces in WWII. The close proximity of Russia and its key strategic air defence areas in the Kola Peninsula and St. Petersburg significantly impact on the geopolitics and role of the Finnish Air Force. Thus, the FINAF's focus has maintained high readiness and developed a quality approach to modern air power. Today and in the future, the FINAF has a crucial role in constituting the backbone of security in the challenging Northern Eastern operational environment.

Finland proudly joined NATO as a full member on 4 April 2023. As a new NATO member, the FINAF strengthens NATO's readiness and credibility. Additionally, the FINAF provides modern and integrated air defence capabilities and forces into NATO's operational planning and force structure. It contributes to NATO's core tasks of deterrence and provides capable air power for NATO's defence in the Euro-Atlantic area. The speciality the FINAF can bring to the table is the knowledge of the Northern operational environment. This expertise particularly includes knowledge of the Russian Anti-Access/Area Denial (A2/AD) network and,

During the air operations exercise RUSKA21, FINAF F/A-18s taxi on one of the Road Bases. The primary objective of the exercise was to demonstrate the Air Force's mobile operational concept using a network of dispersed bases.

of course, the capability of adapting to a harsh climate: how to survive, fight, and maintain operational tempo within the Arctic zone.

The FINAF has evolved over the decades to fulfil its mission in a non-permissive operational environment. To fight within adversary weapon ranges and in contested airspace, the FINAF has created an exceptional fighting doctrine. The doctrine is based on dispersed operations, Agile Combat Employment (ACE), a fully Integrated Air Defence System (IADS), and a multi-domain approach to operations. As the war in Ukraine has emphasized, the significance of dispersed operations in modern air warfare cannot be underestimated; the FINAF has for decades successfully fostered this concept.

Today our Air Force is undergoing significant changes, with the most prominent developments being NATO integration and the F-35 Programme. The most significant capability development programmes are transitioning from F/A-18 to F-35, integration of ISR systems, and procurement of David's Sling high-altitude Surface Based Air and Missile Defence system (SBAMD). Likewise, Nordic cooperation, active participation in international exercises, and NATO's peacetime operations (Air Policing and Shielding) are key components of increasing collective deterrence and defence during peacetime.

Maintaining Readiness and Deterrence, the FINAF Operational Concept

The FINAF places great emphasis on readiness and a prompt QRA (Quick Reaction Alert) response to any potential threats in, through, or from the air domain. In times of peace, the FINAF safeguards and protects the integrity of Finland's airspace on a 24/7 basis with F/A-18 Hornet multirole fighters. Air Force aircraft and units are normally located at the service's Main Operating Bases (Rovaniemi, Rissala, Pirkkala, and Tikkakoski). If a need arises to adjust the readiness level, either in peacetime or in the event of a crisis, aircraft will be dispersed to civilian airfields and road bases.

A recognized air picture compiled of data from mobile and fixed air surveillance radars and other sensors covers Finland's territory and adjacent areas and is the key enabler of the Air Force's air policing mission. Air policing is directed by the Air Operations Centre (AOC) of the Air Force Command Finland (AFCOMFIN), located at Tikkakoski Air Base. Surveillance data is fused and analysed under AOC direction. Integrating our national QRA and NATO's Air Policing assets in the Baltic Sea and High North areas is a vital task in the near future. Some of our F-18s will be tasked to Allied Air Command (AIRCOM) while others will stay in national control.

The operational environment in Finland differs significantly compared to some other Allies. We share more than 1,300 kilometres of a common border with Russia, and the majority of Finnish territory is within the reach of Russian Ground Based Air Defence and Surface to Surface Missile systems, so it is essential to maintain Freedom of Action and Freedom of Manoeuvre. Therefore, agility on the ground and in the air is necessary for our troops and Air Command and Control (AirC2). The conflict in Ukraine and the development of new weapons systems, from drones to hypersonic weapons, have highlighted the significance of dispersed operations, such as ACE, in modern air warfare. For decades, the FINAF has fostered these concepts, doctrines, and Tactics Techniques and Procedures (TTP) for homeland defence, which the Ukrainian Air Force has now demonstrated. The FINAF's resilience, operational agility, and ability to effectively counter the adversary's scheme-of-manoeuvre and degrade their targeting cycle can also serve as valuable examples for other Allies and partners.

The Finnish Air Force's operational concept is based on centralized command and dispersed operations. We must optimize our tactics and procedures to counter the cruise and ballistic missile threat. Air Force operations and resources can be spread rapidly throughout the country. Also, AirC2 is duplicated and dispersed to have a redundant and combat-resistant command and control. In Finland, we can operate from over 30 airfields, which can be used as Main, Remote, or Forward operating bases. These airfields include civilian airports and even highway strips. To increase operational depth, airbases located in the Nordic region outside of Finland, will also be used during times of crisis. In addition to using multiple air bases, the operations within a single base are conducted by dispersing troops in the base area. Logistics, intelligence, and surveillance assets support the mobile and dispersed operational concept.

The annual Finnish Air Force road base exercise Baana allows us to test the capability of various road bases, train airmen, pilots, technicians, air traffic controllers and force protection. Additionally, the annual Air Defence Exercise Ruska provides the FINAF an excellent opportunity to test quick dispersal across the country

A Norwegian F-35 aircraft seen taking off from a Road Base as part of the annual road base exercise Baana 23.

and train the whole Air Force to survive, fight, and maintain an operational tempo against a challenging air adversary. This year's road base event in Tervo also demonstrated NATO allies' capability to operate from highway strips for the first time. The Royal Norwegian Air Force F-35s and Royal Air Force Typhoons made take-offs, landings, and turnarounds from the highway. A minimum logistical footprint and multi-capable airmen are prerequisites for the Finnish Air Force's agile operations during crises and wartime.

Finland's integrated air defence system links fighter operations and SBAMD systems seamlessly. Reducing vulnerability to enemy attacks and adopting dispersed operations will play a crucial role in ensuring success in future conflicts; the FINAF provides an ultimate example of the ability to disperse and operate from austere locations rapidly, and quickly transition between and inside bases.

Integrating the FINAF with NATO

Finland is currently undergoing full integration into NATO, showcasing its strong commitment to collective defence. The FINAF is working closely with new allies to incorporate Finland into NATO across various levels, including the AirC2 structure, standard operating procedures, personnel, and daily activities. The FINAF aims to become a part of the NATO Integrated Air and Missile Defence System (NATINAMDS) and meet NATO's air-basing requirements. Finland's transformation from Partner to full member grants it enhanced defensive capabilities and a greater responsibility to actively engage in collective defence efforts. The FINAF plans to participate in Air Policing and Air Shielding rotations and has demonstrated its ability to seamlessly join NATO-led peacetime operations. Finnish compatibility with NATO systems allows for smooth integration and ensures connectivity in NATINAMDS.

Deepened cooperation with NATO enhances regional security and reaffirms Finland's commitment to collective defence. The next crucial step for the FINAF's integration is to establish zero-day connectivity and define responsibilities in NATO's Air Policing missions.

The FINAF demonstrates the ability and solidarity to contribute to NATO's deterrence through Air Shielding and Air Policing and preparing for air operations throughout NATO's operational areas. Defending the homeland with allies is a clear priority. We will assign troops to NATO's force structure at home and abroad as necessary and maintain their deployment and

Multiple aircraft formations actively engaged in the Arctic Challenge Exercise 2023, showcasing their skills and capabilities in this prestigious event.

combat readiness. Together with NATO, the FINAF will build main bases to meet NATO requirements and build national command and control links so that they can be linked to NATO's classified networks. Regarding NATO's operational and strategic planning, the FINAF incorporates NATO's identified needs into our national planning process.

Contributing to NATINAMDS by providing surveillance and interception capabilities for the Alliance is a high priority. The FINAF develops air power, air defence, JISR, and targeting to improve NATINAMDS as well as a Multi-Domain Operations capability. The Air Force's training, exercise, and operational concept will be renewed in 2025 so that our expertise and actions more broadly support the skillsets required by NATO's complex operational environment. Our national training programmes will be adjusted to complement NATO training events and exercises.

Training and Exercises: Strengthening Nordic and Multinational Cooperation

International cooperation forms a major part of the daily activities of the Air Force. The objective of cooperation is to share information and expertise with key actors and create opportunities for cost-effective training. The Air Force has sought know-how and ideas outside Finland's borders in many different ways throughout its history. Through international connections, the Air Force gains a grandstand view of the global development of military aviation and an opportunity to practice its operations with the foremost air forces in the world. By participating in multinational training and exercises, the Air Force can adopt the best practices and operating procedures from around the world as a part of its activities and compare its capability to the international operating environment.

© Finnish Air Force

As a small country, Finland must concentrate efforts on education and training. The Finnish Air Force keeps its pilots, ground crew, and equipment at peak efficiency with an extensive national fighter pilot training programme, a versatile Training & Exercise (TR/EX) programme, and continuous modernization. Regular drills, exercises, and simulations (including Live, Virtual, Constructive (LVC) training) enable the FINAF to sharpen its skills and enhance its operational capabilities, ensuring a swift and effective response to potential security challenges. All these training events and exercises are now open to our partners and allies.

The Finnish Air Force trains and operates under demanding Arctic conditions due to the country's geographical location. Training in Arctic conditions is an integral part of Finland's annual TR/EX schedule; thus, it is part of normal operations rather than a training aim. Additionally, vast, sparsely populated areas for long-range Beyond Visual Range engagements and Joint Air Land Integration areas ensure the FINAF's attractiveness for multinational and joint all-domain cooperation. This also creates an excellent opportunity for Finland to host and lead training events for all of NATO under challenging arctic conditions.

Due to its strategic location and shared security concerns, Finland has strong, longstanding ties with neighbouring Nordic countries. They regularly conduct cost-effective weekly cross-border training, including Dissimilar Air Combat Training (DACT), small Composite Air Operations (COMAOs) and biennially organized flag-size Arctic Challenge Exercises, involving over 100 aircraft from Finland, Sweden, Norway,

The Air Chiefs of the Nordic Countries from left to right: Major General Rolf Folland of Norway, Major General Juha-Pekka Keränen of Finland, Major General Jan Dam of Denmark, and Major General Jonas Wikman of Sweden. The Nordic Cooperation Framework provides a platform for the Finnish Air Force to engage in collaborative efforts with other regional air forces, thereby enhancing security and stability in the region.

and Denmark. These Cross-Border Training missions (CBT) save on logistics costs by using home bases and often include participants from the US Air Forces in Europe. Along with fighter planes, AWACS and in-flight refuelling aircraft also take part in these missions.

The Nordic Cooperation Framework (NORDEFCO) serves as a platform for the FINAF to collaborate with other regional air forces, further strengthening security and stability. Also, the UK-led Joint Expeditionary Force has proven to be a valuable framework for training and collaboration with other air forces in the Baltic Sea and High North region.

The recently signed Nordic Air Commanders' vision aims to strengthen Nordic Air Forces' ability to conduct joint air operations from peacetime to full-scale air operations in wartime. The goal is a modern combat-resilient Joint Air Command and Control system capable of planning, executing, and commanding air operations in contested air space. The noteworthy fact is that the Nordic Air Forces together have more than 250 modern 4th and 5th gen fighters. A strong, combined fighter fleet with a credible air and missile defence posture will holistically support air power use in the Nordic region and pave the way for seamless integration of Air Defence in the area. Simultaneously, Nordic Air Force cooperation strongly reinforces and contributes to NATO's Federated Mission Networking, peacetime Air Policing, and integrates NATO's operational plans. We take advantage of the increased operational depth and perform as a leading expert in dispersed operations. By doing this, we contribute to the effective command of the Nordic Air Forces and the development of air operations to meet the Alliance's collective security requirements.

Leveraging High-End Air Warfare Capabilities and Integration of F-35

The main contributors to Finland's air defence are the Air Forces F/A-18C and F/A-18D Hornet multirole fighters. To maintain a robust defensive capability, the Hornets have undergone a series of upgrades to enhance their air-to-air and air-to-ground capabilities. The goal is to use these upgraded Hornets until the introduction of fifth-generation F-35 multirole fighters. The F-35's cutting-edge technology, versatility, joint ISR, supportive capabilities, and increased multi-layered Air Defence will significantly bolster Finland's and NATO's north-eastern flank defence posture. Finland has selected the F-35 Lightning II as the future backbone of its air force for its advanced stealth, joint warfighting capabilities, and interoperability with NATO allies. The procurement process reflects Finland's commitment to maintaining a strong air force and aligning with NATO forces.

The F-35 Programme is making significant progress in Finland with plans for procurement, including 64 fighter jets, advanced weaponry options, training, and maintenance services until 2030. This system will replace the Hornet fleet in Finland by 2030, with optimized weapons procurement, including AMRAAM, Sidewinder, Small Diameter Bomb (SDB) I and II, Joint Direct Attack Munition, Advanced Anti-Radiation Guided Missile Extended Range (AARGM-ER) and Joint Air-to-Surface Standoff Missile Extended Range (JASSM-ER), ensuring maximum capability in their operating environment. A dedicated F-35 Programme organization has been established within the Air Force and Joint Logistic Command, while infrastructure construction and training preparations are ongoing at air force bases. Initial training for a select group of FINAF pilots and maintenance personnel will begin in the US in 2025, followed by operations in Finland starting in 2026. As the integration process takes several years, there will be a constant focus on developing operation tactics and techniques through training and advanced simulators. The Lapland Air Wing and Karelia Air Wing will house the F-35s at Rovaniemi and Rissala, respectively, highlighting their importance in enhancing the FINAF's fighting doctrine.

Lockheed Martin is making progress on the F-35 Programme, with production of the first Finnish F-35 fighter beginning in Texas, USA. In 2023 we received the ceremonial first part of this aircraft at the Turku Air Show, symbolizing an important step in the programme. The impact of the F-35 extends beyond the Air Force and influences the Finnish Defence Forces system. Cooperation and integration with other services are crucial, emphasizing a comprehensive, multi-domain approach. The F-35's design considers the operating principles of the Air Force and the joint capability requirements of the entire Defence Force. Joint war games have been conducted to assess how the F-35 supports the defence system, and Finland has successfully joined the global F-35 user community since February 2022.

The ongoing Pohjanmaa-class vessel programme of the Navy, the Finnish Army SBAMD Capability Replacement Programme, the Air Force Integrated Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) System programme, and, of course, the F-35 programme will all have a significant impact on air defence and the entire defence system in the coming years. In spring 2023, a procurement decision was made on the all-altitude ground-based air and missile defence capability for the Army. The chosen system was the David's Sling missile system, providing a new aspect to air and missile defence. Furthermore, Finland's Integrated Air Defence-system seamlessly links fighter operations and ground-based air and missile defence operations together.

Whether procurement, technological integration, operational concept, or Human-Machine Interface, we have ensured that Finnish AirC2 structure and network are both state-of-the-art and interoperable. The layered nature and area coverage of ground-based air and missile defence capabilities will also be maintained, and the targeting capability will be developed. The Defence Forces will respond to the growing drone threat by improving its counter-drone capabilities. The integrated Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR), and Command and Control (C2) system will be further developed to improve the prerequisites for commanding and controlling air operations. Furthermore, cyber and space capabilities significantly influence ISTAR and C2 system development.

The FINAF ground crew refuelling a Finnish F/A-18 at a road base in Joutsa, showcasing the capability to operate from highway strips.

Conclusion

The Finnish Air Force's steadfast commitment to readiness, air policing, advanced aircraft procurement, NATO integration, Nordic cooperation, and active participation in international exercises underscores its pivotal role in national defence and regional security. Through a combination of modernization efforts, strategic partnerships, and operational excellence, the FINAF remains prepared to safeguard Finnish and NATO airspace and contribute to international peace and stability.

In the future, the Finnish Air Force will be operating the F-35, David's Sling, National Advanced Surface-to-Air Missile System (NASAMS), and a variety of different modern air surveillance systems. All these will be integrated by design and interoperable by demand.

We are proud to join the Alliance and bring our value to the table, but we remain humble to keep ourselves up to date and on the edge!

ABOUT THE AUTHOR

Major General Juha-Pekka Keränen

Commander of the Finnish Air Force

Major General Juha-Pekka Keränen joined the Finnish Air Force in 1987. His first 20 years in the Finnish Air Force were primarily connected to fighter activities. His career progressed from fighter pilot duties to flight and squadron commanding. Major General Keränen has flown Hawk Mk51, MiG-21BIS and F/A-18C/D fighters, with the latter being his main aircraft. In 1996 he was trained at VFA-125 NAS Lemoore, receiving F/A-18 qualifications. He has over 3,000 hours of flight experience and he still flies the F/A-18.

Major General Keränen has worked in Defence Command Finland to represent the Commander of the Finnish Air Force in strategic and operational planning. He served as Commander of Satakunta Air Command in 2015, Deputy Chief of Staff of AFCOMFIN in 2017 and Chief of Staff of AFCOMFIN in 2021. Major General Keränen was also the Director of the Finnish Fighter Replacement (HX) Programme between 2017 and 2021. On 1 June 2022, Major General Keränen was appointed Commander of the Finnish Air Force.

MDO requires a digital transformation, adaptive leaders, and Command and Control Systems to operate across all domains.

The Alliance's Transition to Multi-Domain Operations

An AIRCOM Perspective

By Squadron Leader Shaun Cannon, UK Air Force, HQ AIRCOM

Introduction

The concept of Multi-Domain Operations (MDO) has gained prominence in the context of NATO's military strategy. What started years ago as an operational answer to peer adversary competition, in particular, to counter the Russian Anti-Access/Area Denial (A2/AD) threat, has become one of the most challenging endeavours NATO has ever undertaken. The challenges posed by a peer adversary's A2/AD posture represent the manifestation of the changing and unpredictable battlespace of the future. This multi-layered, multi-threat, highly dynamic, omnidirectional, and far-reaching multi-domain system-of-systems forced NATO to re-think its approach to effectively and efficiently implement the Military Instrument of Power (MIoP). Additionally, the increased competition in the cyber and space domains raises new complexities to be dealt with during operations.

Future operational concepts must ensure that NATO's core tasks can be executed across the full spectrum

NATO's MDO approach is not just a more enhanced version of Joint Operations.

from peacetime to conflict, and under all conditions. Therefore, NATO must have the capability to continuously understand the changing environment and consequently develop strategies to sustain an operational advantage.

On 19 May 2023, all NATO nations approved the Alliance Concept for MDO. This formally signalled NATO's transformation from a joint approach, focused on the military services, to a multi-domain approach. The NATO definition of MDO is 'the orchestration of military activities, across all domains and environments, synchronized with non-military activities, to enable the Alliance to deliver converging effects at the speed of relevance'.[1]

This definition recognizes the complexity of the modern operating landscape and the increased presence of non-military entities at all stages of conflict, while retaining the centrality of force as a response to military problems. The Alliance's agreed vision is that its approach to MDO will enable NATO members to prepare, plan, orchestrate, and execute synchronized MIoP activities across all domains and environments, at scale and speed, in collaboration with other non-military Instruments of Power (IoP), partners, and stakeholders.[2] Realizing this vision will require tailored options delivered at the right time and place which build advantage in shaping, contesting, and fighting. This distributed yet coherent approach presents a multitude of dilemmas which can decisively influence the attitudes and behaviours of adversaries and relevant audiences by adapting faster than the adversary can respond.

The purpose of this article is to demonstrate that MDO requires a digital transformation, adaptive leaders, and Command and Control (C2) systems that can operate across all domains. Synchronized interactions are necessary with non-military IoP, and thinking must extend beyond the joint mindset.

Joint Operations and Multi-Domain Operations

Born from the need to work together seamlessly in the most demanding circumstances, 'jointness' remains an important part of military doctrine. It is the basis upon which the MDO-related thought is built.

But the complexities we face today show that joint doctrine alone is insufficient for the military challenges of our era. The operational domains of space and cyberspace have unique characteristics that cannot simply be incorporated into existing joint doctrine, as many critical capabilities within them are not owned by militaries. The proliferation of non-military actors that contribute to military success, including commercial entities, has intensified over the past several years. These actors must be considered during the planning and execution of military operations. Indeed, there are other considerations, such as changes in military culture that reflect broad social evolution. Social media is among the factors that need to be weighed in military operations of the 21st century. Simply put, joint doctrine alone, even if executed flawlessly, is insufficient for the context in which forces of the Alliance are expected to operate, both today and in the future.

Therefore, NATO's MDO approach is not just enhancing joint operations by simply adding new domains. It is not only about using as many domains as possible when planning for effects, and it is more than actions and effects in one domain supporting another (supported – supporting interrelationship concept).

NATO's MDO approach mainly relates to a change of mentality when planning and executing modern operations in order to orchestrate effects in all dimensions (physical, virtual, and cognitive), across all domains (maritime, land, air, space, and cyberspace), at all levels of command, and using all alliance IoP (military, information, political and economic). Currently, effect development is taking place at the service level. Services are looking primarily into effects in the domains they traditionally operate in. Effect development in MDO should take place from a domain perspective that is service agnostic. This small, but significant, paradigm shift increases the number of options and ensures that capabilities are employed more effectively than they are today. It is about combinations of capabilities and actions in and from multiple domains being able to converge as a collective threat or opportunity.

In other words, NATO's MDO approach is a shift in mindset from viewing operations through the prism of component commands' capabilities to seeing the delivery of complementary effects across interconnected domains, with the aim of forcing adversaries to defend all domains continuously from all directions, thereby imposing multiple dilemmas on the adversary to expose vulnerabilities which can be exploited.

Principles of MDO

MDO is a logical evolution from joint to an approach that exploits domain capabilities irrespective of which military service or non-military provider has ownership of the resource. NATO's MDO Concept for the Alliance describes the agreed four guiding principles that are fundamental to NATO's successful conversion to an MDO-enabled Alliance: *unity*, *interconnectivity*, *creativity*, and *agility*. NATO's digital transformation effort underpins these principles. It fuses military assets and connects non-military actors so that they, through collaboration, coordination, and synchronization, can contribute to successful MDO.

- *Unity* is as important for MDO as it has been for joint or coalition warfighting, and for delivering a comprehensive approach while emphasizing the criticality of information sharing.
- *Interconnectivity* enables the exchange of data and information to build understanding, whether or not the tactical units are interoperable.
- *Creativity* is what staff and commanders will need in order to build blended multi-domain warfighting options and to appreciate what data may be available to support military activity.
- *Agility* focuses on improving speed, from tactical resupply to strategic understanding. It enables agility in decision-making across all levels and in defensive and/or offensive actions.

The following four enablers underpin the Alliances transformation to MDO:

1. Data and Digital Transformation

MDO demands a data-centric approach that recognizes data as a strategic asset.

MDO demands a data-centric approach that recognizes data as a strategic asset.

Given the sophistication of modern capabilities, it is self-evident that digital transformation will be the key to unlocking the full potential of MDO. If the Alliance is to achieve its vision of MDO, then it will have to digitalize; there is no way to conduct MDO at the speed of relevance without it.

The Alliance needs to connect with one another via systems with sufficient capacity to enable persistent interaction. Digital transformation efforts, with regard to MDO, tend to gravitate towards technical specifications and the substantial investment in NATO's digital backbone. This is a welcome effort; however, for NATO to achieve the highest aspirations of MDO, it must widen the aperture regarding digital transformation beyond technology to include culture, processes, and people.

A common refrain in military circles is that joint culture took two generations to form within forces of the Alliance. Yet, advocates of MDO maintain that NATO forces lack the luxury of two generations to adapt to an MDO culture. NATO must be proactive and incentivize the cultural precepts that underpin an MDO mindset. It is crucial for a modernized NATO to have individuals who are skilled in handling data, as this field has its own set of skills, practices, and norms. How forces of the Alliance reconcile military culture with that of data science within an MDO framework is a significant undertaking with potentially percussive benefits across the enterprise.

NATO will need to consider how artificial intelligence can help harness large data sets to enable elegant and exhaustive operational pictures that underpin effective MDO. Moreover, NATO's needs to refine and automate its processes and move human labour beyond the critical path of routine administration in order to achieve the requisite gains in speed and scale that MDO demands.

2. Exploiting the Technological Advantage

MDO must be optimized through the effective exploitation of technology that provides information and decision advantage. This includes the use of Emerging Disruptive Technologies (EDTs), particularly Artificial Intelligence (AI), and the transition to a data-centric organization via the NATO Digital Transformation Implementation Strategy (DTIS). These will unlock opportunities to advance interconnectivity and interoperability across national forces and the other Instruments of Power.

EDTs bring opportunities for secure communications, situational awareness and decision-making and can support commanders in visualizing, testing, generating, and executing activities across all domains. Nations are exploiting EDTs at different rates, which creates a challenge for MDO interoperability. Furthermore, AI can potentially increase the speed and accuracy of data analysis, accelerating the commander's ability to react. As technology accelerates, AI provides opportunities to assist decision-making through the integration of highly automated functions. Whilst NATO must take advantage of technological advancement, responsible use of AI must be paramount before AI-assisted decision-making is integrated with NATO military forces.

'A common refrain in military circles is that joint culture took two generations to form within forces of the Alliance. Yet, advocates of MDO maintain that NATO forces lack the luxury of two generations to adapt to an MDO culture.'

The war in Ukraine has demonstrated how another disruptive technology, Unmanned Aerial Systems (UAS), have given Ukrainian Forces an asymmetric advantage in what was initially expected to be a conventional conflict dominated by a larger aggressor. UASs have traditionally been used as an Intelligence Surveillance and Reconnaissance (ISR) tool to gather information on an adversary but have also been harnessed for applications such as communications and jamming. Open-source media has broadcast videos of Russian soldiers driven from their trenches at the threat of a mortar round being delivered on their position by an unmanned system, which is a significant disruptor in modern warfare.

EDTs can be big or small, and, like small UASs, don't have to be particularly high-tech or expensive. Further, by definition, EDTs are a shifting landscape, not predictable beyond the near future.

3. Cross-Domain Command

MDO is reliant on collaborative, agile, and empowered C2. The Alliance's standing military structures (NATO Command Structure and NATO Force Structure) are unique amongst the instruments of power. Integrated military structures provide the Alliance an advantage in any contingency, regardless of its nature. Future success of the Alliance's MIoP depends not only on preparation, capability, and agility of forces, but also the ability of commanders to operate in a complex operating environment simultaneously across physical and non-physical domains. This requires cross-domain understanding and agile and asymmetrical thinking supported by robust and continuously refreshed information and communications systems. Against this backdrop, traditional methods of command will have to evolve, continuing to embrace the flexibility and advantage of mission command.

NATO must review and, as necessary, adapt and advance current conceptual approaches towards a multi-domain perspective. Moreover, the traditional 'Art of Command' must transform into a modernized Cross-Domain Command that embraces a more agile and flexible approach.

Building upon ongoing efforts to adapt and modernize C2, the Alliance is adopting an incremental and evolutionary approach. Recognizing work already initiated by both NATO Strategic Commands and building on the approved MDO Concept, the Cross-Domain Command Concept will focus on medium to long-term conceptual development of NATO C2 into a future Cross-Domain Command.

4. Education, Training, Exercising, and Experimentation

Progression towards MDO will need investment in technologically-enabled training at the national and NATO levels. It will also require commanders and staff that can exploit capabilities across the domains, based on technologically enabled understanding, to creatively generate relative advantage.

The development of multi-domain warfighters and cross-domain leaders through the linkage of professional military education, training, and operational requirements must be a priority for NATO. NATO's MDO Concept emphasizes the need for warfighters and leaders that are not only domain specialists but also are capable of exploiting strategic, operational, and tactical opportunities across all five domains while operating across multiple instruments of power.

Achieving this is a complex task. Alliance members will need to develop their professional military education (PME) and training programmes in a manner that meets the requirements of MDO. This will require the introduction and emphasis on new subjects and educational approaches that will develop creative and critical thinking, leverage the strategic, operational, and tactical advantages that multi-domain operations will provide, and will take into consideration adversary multi-domain capabilities. Additionally, digital education – from the flight line to the Four Star – will gain particular importance.

'To support the Alliance ambition of transforming towards an MDO-enabled Alliance with capabilities to deter and defeat adversaries across the five operational domains in an orchestrated and synchronized manner, the MIoP must evolve.'

Across NATO, there will need to be an unprecedented alignment of PME and training end states. Greater interoperability at the operational level is best supported by greater interoperability at the nexus between education and training. However, the Alliance should support the simultaneous retention of national requirements and priorities in member states' professional military education and training programmes. Whilst NATO has a role to play, the main effort remains a national responsibility.

Technology will play a vital role by taking NATO PME and training to a new level of authenticity that will lead to enhanced levels of readiness. Initiatives such as the next generation of Modelling & Simulation (M&S) tools will enable NATO and Allies to leverage the power of experimenting, modelling, simulation, and wargaming. Allies will also need to develop programmes which emphasize the persistent use of such tools in order to maintain a high level of readiness and enable the Alliance to fight and win in all future operating environments.

Wargaming and experimentation, both powerful analytic methods, can lend incredible insight into the complexities of MDO across NATO, not only in the analytic and planning communities, but also in the training and education communities. Experimentation and wargaming are uniquely suited to the exploration of new ideas, concepts, and capabilities, and will play a critical role in implementing MDO for NATO. When combined with EDTs, tools like next generation M&S, the ability to generate understanding in NATO's training and education enterprises will be almost limitless. However, a cultural change will be necessary to truly test and experiment during exercises.

MDO and Synchronization with Non-Military IoP

The same trends that are driving NATO to develop its MDO Concept are also increasing military operations' reliance on and interaction with non-military IoP. These trends include the proliferation of sensors, the rapid expansion of civilian space-based assets, the increasing importance of cyber to enable military operations, and the vulnerability of civilian infrastructure to kinetic and non-kinetic attack during wartime. Each trend necessitates more focused coordination of military and non-military IoP.

To succeed, military operations must be multi-domain and be built on a strong backbone of synchronization

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Technology that provides information and decision advantage can optimize implementation of the MDO concept.

with non-military IoP. Allied Command Transformation (ACT) has recognized this interdependence in its definition of MDO and achieving this will require immediate steps to further coordinate with non-military divisions of government and private-sector actors. It will also require a more concerted approach to incorporate these elements into NATO planning processes in the long term.

'After decades of low-intensity conflict, Russia's invasion of Ukraine has reintroduced large-scale, high-intensity combat to Europe.'

Ukraine's remarkable defence against Russia's brutal war of aggression demonstrates how MIoP connects with and depend on non-military IoP. Ukraine's use of Starlink for C2 is well-documented, for instance, even as recent comments from the SpaceX CEO demonstrate potential drawbacks to relying on the private sector for Low-Earth Orbit (LEO) enabled C2 infrastructure.

In addition to communications, Ukraine utilized commercial space capabilities to complement government-provided satellite imagery intelligence to great effect. Ukraine further leveraged the proliferation of private sensing available by incorporating publicly available information into its intelligence and targeting. In addition to turning to private-sector capabilities to improve combat effectiveness, Ukraine also had to address challenges posed by its reliance on private industry, critical infrastructure, and the private sector companies that operate and maintain said infrastructure.

The stress this war has put on the global industrial capacity and the air, land, and maritime lines of communication feeding into Ukraine have reminded military and non-military planners alike of the adage that logistics win wars. Hence, when Russia's initial invasion failed, it quickly ramped up a barrage of attacks on

NATO's adversaries have sought to limit NATO's access to the battlespace and to deny key operating areas.

Ukraine's transport, energy, and cyber infrastructure using both kinetic and non-kinetic means. Ukrainian ingenuity, coupled with support from military partners and private-sector actors, has enabled Ukraine to both sustain its war effort and continue to provide the basic functions of governance as a state. Ukraine has benefited from a protected rear support area for logistics in NATO nations, as well as the ability to draw on industrial capacity from the many nations donating to its armament. It is important to keep in mind that these advantages – protected industrial and logistics sustainment capacity – would not necessarily apply if NATO itself was in a large-scale conflict.

NATO will need to leverage private-sector capabilities across domains in order to enhance lethality. It also will need to deepen its industrial base capacity and protect critical infrastructure from kinetic and non-kinetic attack. All of this will require synchronizing the military instruments across the warfighting domains of air, land, maritime, cyber, and space with non-military IoP from governments and the private sector. Though Ukraine has done an exceptional job of fostering this government-private sector cooperation during a wartime environment, it also spent the past eight years of its low-intensity conflict with Russia to harden its infrastructure and work with the private sector and across all levels of its government at all levels to prepare for and fend off Russian kinetic and non-kinetic attacks. If NATO faces a similar conflict, it will need to synchronize military and non-military IoP before the first physical shot is fired.

So What for AIRCOM?

Moving forward, AIRCOM must fully engage with the Alliance's transition to MDO and seize the opportunities that this offers to advance the Alliance, and AIRCOM, from the 'now' to the 'future'. The five priorities below will enable AIRCOM to be at the forefront of the Alliance's evolution towards MDO. Each priority not only contributes to achieving an MDO-enabled Alliance but also contributes to NATO air forces that are

'integrated by design' (IBD); collectively they form the AIRCOM Integrated By Design Campaign Plan (IBDCP).

1. Counter-Anti-Access / Area Denial (C-A2/AD)

Russia and others have studied the West's way in warfare for over 30 years, and Russia learned that air and space power is the foundation on which everything else is built. Accordingly, NATO's adversaries have sought to limit NATO's access to the battlespace and to deny key operating areas. The war in Ukraine highlights what happens when neither side can gain air superiority: a prolonged, artillery-heavy slugfest with tens of thousands of casualties. This is not how NATO or our nations want to fight. Instead, NATO needs to take down the Long-Range Surface-to-Air Missile (LRSAMs) systems and coastal defence cruise missiles that particularly limit air freedom of manoeuvre but also inhibit land and maritime operations.

A significant AIRCOM conceptual effort is focused here, to ensure that all of NATO's air forces can bring their best operational capability to ensure access in all domains, but especially air, land and maritime. AIRCOM is breaking new ground to tackle this problem and hosted a two-week event that brought together SMEs from NATO air forces and other domains to address key problem sets and provide focused, achievable, near-term enhancements – this being an inaugural Weapons and Tactics Conference (WEPTAC), the first of its kind in AIRCOM or NATO. MDO contributes to the C-A2/AD fight by employing capabilities from all components across all domains. Thorough peacetime planning enables a truly integrated approach with the benefit of deliberate mission command.

2. Integrated Air and Missile Defence (IAMD)

To the extent that NATO needs to dismantle our opponents' C-A2/AD capability, the Alliance also needs to ensure that it is able to defend NATO territory, its people, critical infrastructure, and essential defence capabilities. After over 30 years of relative peace in Europe, NATO needs to bring IAMD back to the forefront. AIRCOM briefed at many events over the past year, including to the NATO Military Committee and at Supreme Headquarters Allied Powers Europe (SHAPE)-

led IAMD exercises, and engaged with all 32 NATO nations' Air Chiefs. AIRCOM will continue applying considerable attention to IAMD to defend every inch of NATO territory and airspace. Again, the WEPTAC is a key activity to help galvanise collective capability. MDO helps to identify peacetime capabilities from all components that can be integrated into an IAMD construct. No capability should be spared. Reluctance of component commanders to 'lose control' over own capabilities must be overcome with the promise of more effective integrated solutions. Concepts like Air Support Operations Centres should be assessed concerning the use of IAMD functions, rather than air-land integration alone.

3. Air Command and Control (AirC2)

There's no point in having great capabilities – fighters, SAMs, radars, and munitions – if a command is unable to ensure they are employed effectively. This requires an appropriately designed AirC2 systems approach; hence C2 is another key priority. The war in Ukraine has also underlined the need for survivability, redundancy, and the ability to operate when communications are denied or degraded. AIRCOM is looking hard at what this means now and in the very near-term – from how we train commanders and staff, through testing distributed C2, to the equipment that allows us to prosecute air operations at scale within an increasingly complicated battlespace. AIRCOM has an excellent history to build upon, and some exciting technology to embrace. But most importantly, AIRCOM will get NATO AirC2 on track for a future Multi-Domain C2 (MDC2) construct. MDC2 is more than connecting networks, it requires doctrine, training, personnel, and leaders with an MDO mindset. It requires application of flexible C2 concepts, like mission command and command by negation, to stay flexible and adaptable. MDC2 requires the empowerment of commanders at the lowest practical level of the organization. It requires commanders having the understanding and the trust to delegate


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NATO needs to regain agility and interoperability in how aircraft are supported and maintained.

Liberal information sharing policies between Allies and Partners are crucial to create the level of shared understanding necessary to combine effects across all domains.

authority to the lower levels of the organization in a timely manner when the situation demands it.

4. Information Sharing

MDO is based on shared situational understanding. Situational understanding is based on shared situational awareness. Sharing of information is crucial to create the level of understanding necessary to develop the combinations of effects across all domains to which MDO aspires. Information-sharing holds the most promise on return with the lowest cost assuming problematic policy barriers can be overcome. NATO must ensure that restrictive rules and processes guarding what information can be shared within the Alliance do not unnecessarily hold us back. Each nation needs to assess and – where appropriate – overcome outdated and overly restrictive policies. Two examples: the US now shares 3,000 points of interest a month with NATO allies…previously it was only 30 a month; and more information on the F-35 has been shared at the WEPTAC than was ever achievable before. Both of these improvements cost nearly nothing – they were simply policy restrictions that were removed through engagement, risk assessments, and thoughtful discussion. But if the Alliance wants to think of data centricity in MDO, it needs to get the information exchange across NATO correct.

5. Agile Combat Employment (ACE)

NATO needs to regain agility and interoperability in how aircraft are supported and maintained. These are skills and knowledge NATO worked hard to develop and practice during the Cold War, but which were not maintained in recent decades. Ongoing work to progress ACE and supporting elements such as Aircraft Cross Servicing (ACS) is geared to correct this shortfall, increasing the survivability and operational effectiveness of our aircraft and systems while posing problems for adversaries. Once again, the war in Ukraine highlights the need to avoid being predictable and thus easily targeted. It also demands speed and responsiveness to deploy and redeploy as required. Nations have different versions of ACE, but there are some common themes and requirements AIRCOM will develop together, such as ACS and the necessary level of secure fixed and mobile digital communication and information systems.

Conclusion

MDO is a critical component of NATO's military strategy. The integration and synchronization of capabilities across different domains are necessary to overcome the complex and interconnected challenges of contemporary warfare. Key components of MDO include interoperability and synchronization among different domains, the use of modern technologies, and effective planning and execution. The driving factors behind MDO include the evolution of technology, the changing character of warfare, and the need for a coordinated response to global threats utilizing all IoP.

MDO extends joint concepts and emphasizes the importance of domains rather than the military force operating in them. A strategically-aligned Alliance equipped with MDO capabilities will have the ability to seize opportunities throughout all stages of conflict, including shaping, contesting, and fighting. This advantage extends from tactical engagements to strategic operations, and can be leveraged in collaboration with partners. New structures for command and control help amplify this focus on domains and provides increased options for warfighting commanders.

The ongoing conflict in Ukraine has been a case study in the evolving character of warfare and the challenges that arise. It shows the criticality of operating in the cyberspace and space domains, the utility of technology like drones and autonomous systems, the importance of adaptive leaders who can deliver effects across multiple domains at speed and scale, and the potential risks of relying on non-military IoP.

Implementing the Alliance Concept for MDO and NATO's transformation into a multi-domain enabled Alliance is a true Bi-Strategic Command endeavour. MDO will shape the future of deterrence and defence in the North Atlantic area of operations. Working together to achieve the MDO vision, AIRCOM remains a relevant actor in this changing environment and, through the IBDCP, fully contributes to the Alliance's evolution towards MDO.

The time for getting our concepts, doctrine, tactics, techniques, and procedures right to fight and win a peer adversary fight is now. Let's not waste time. Let's accept the challenge and push hard to get NATO Air Forces ready. Fight's on! ●

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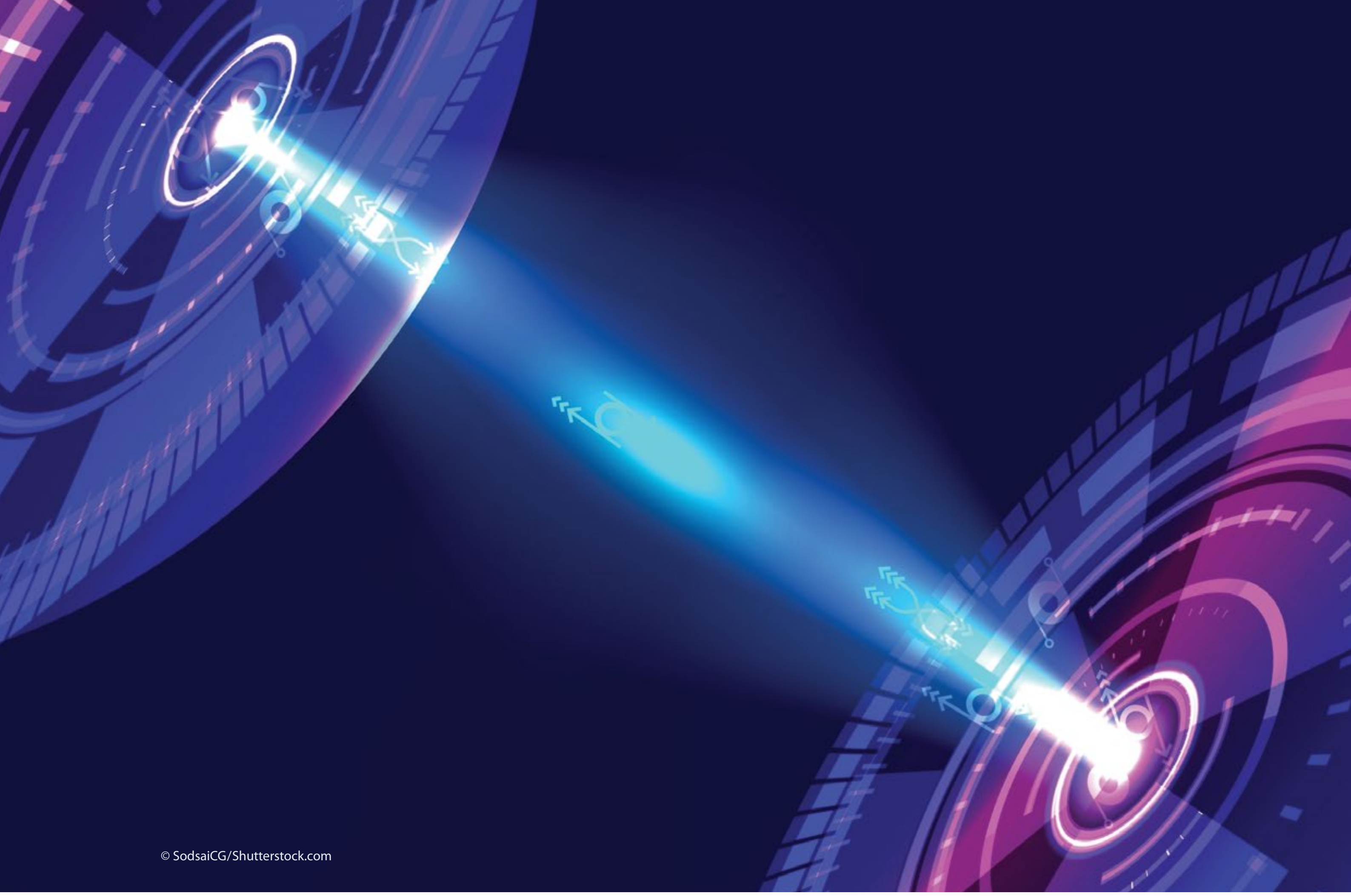

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Quantum Technologies for Air and Space (Part 2 of 3)

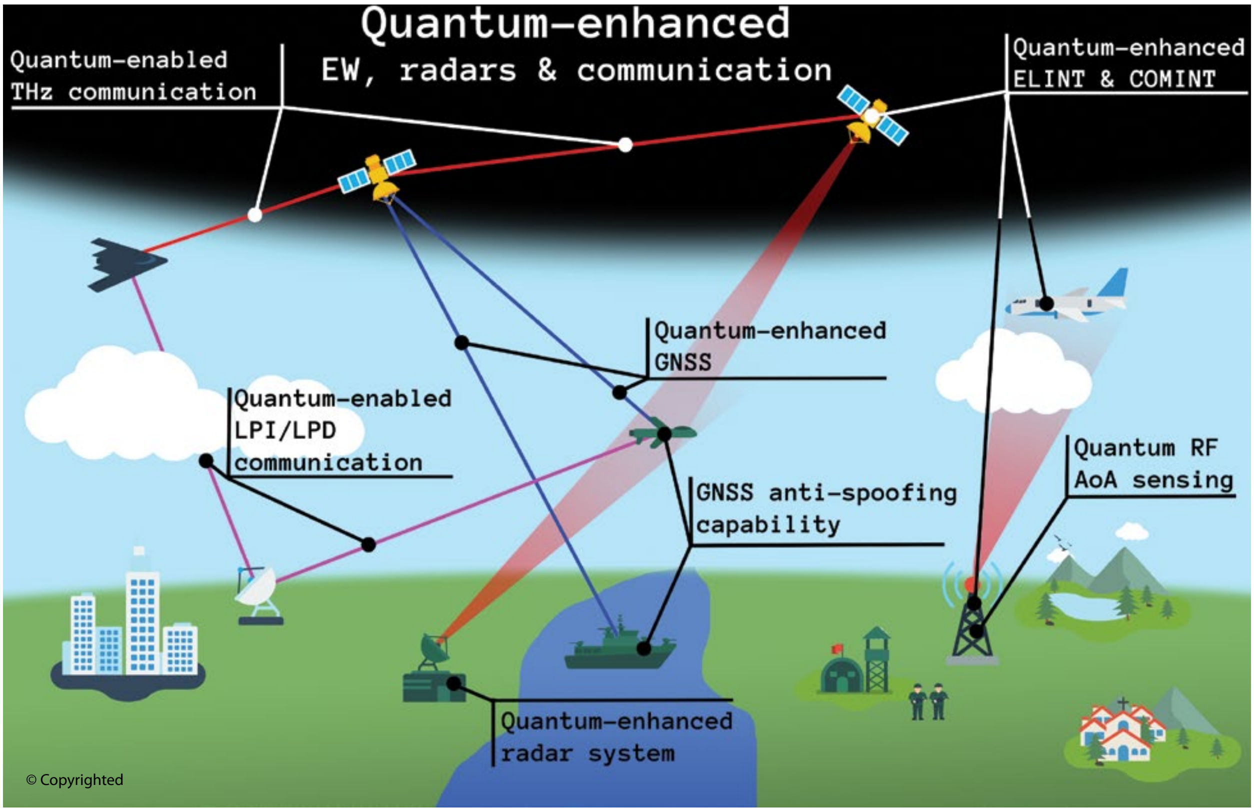
Quantum-Enhanced Radars and Electronic Warfare: Use Cases and Timelines

By Dr Michal Krelina, Czech Technical University, Prague

Introduction

This article is the second instalment of a three-part series that delves into the realm of Quantum Technology (QT). Specifically, it explores the applications of this cutting-edge field within the military's Air, Space, and Cyberspace domains. The article aims to shed light on the quantum technologies that hold promise for operational viability in the near to mid-term future.

Building upon the foundation laid in the previous article, titled 'Quantum Technology for Defence – What to Expect for the Air and Space Domains,' published in the JAPCC Journal 35 Winter edition, we now embark on a deeper exploration of this captivating subject. In our initial piece, we introduced readers to the second quantum revolution, providing a comprehensive overview of the fundamental theory and concepts of QT. Additionally, we highlighted three fundamental applications of QT, namely quantum computing, quantum

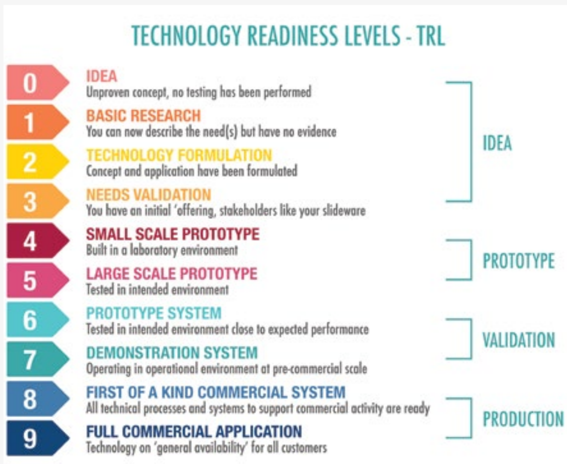


As quantum technology matures, we can expect application across all domains, with potentially disruptive effect.

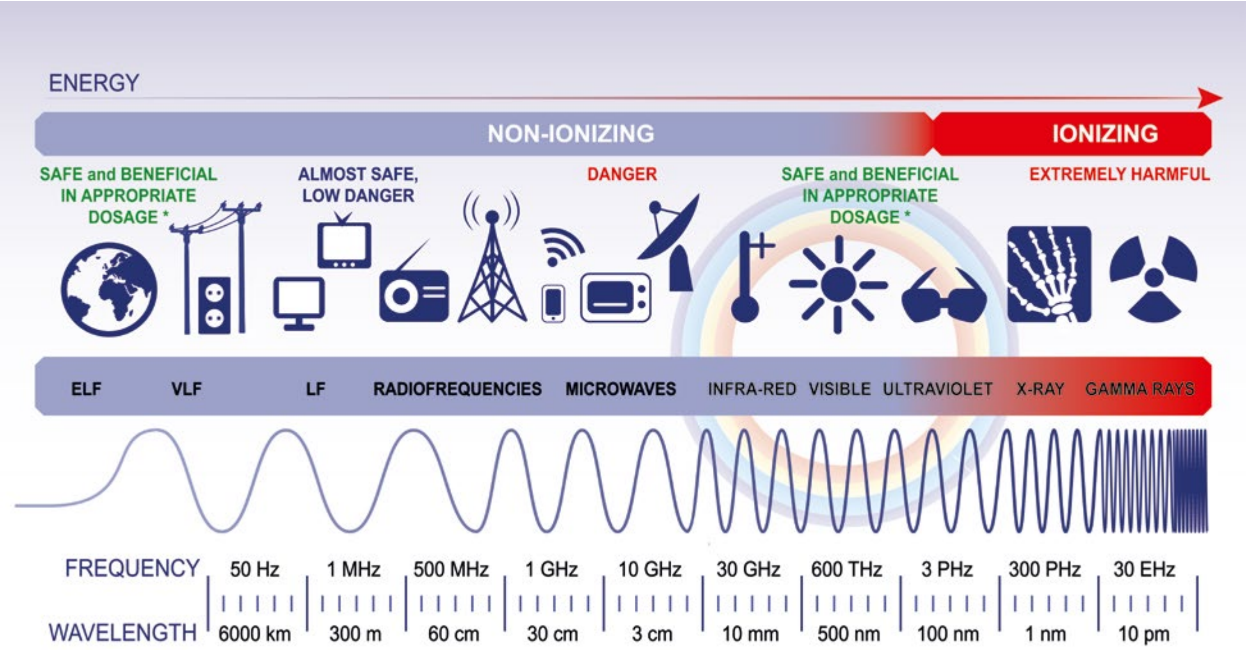
networks and communication, and quantum sensing and imaging. Our aim was to dispel any misconceptions and help our readers establish realistic expectations for this burgeoning field. Now, in part two, we will delve into the intricacies of quantum-enhanced radar and electronic warfare, unravelling their complexities and shedding light on their potential implications.

QT is a young and dynamic field that harnesses quantum properties like superposition and entanglement at the fundamental level of individual quantum systems, such as electrons, ions, and atoms. With significant potential in military applications, many quantum technologies are particularly relevant to the air and space domains. Even long before quantum technology became a buzzword, institutions like Defense Advanced Research Projects Agency (DARPA) recognized its potential, supporting research that has now come to fruition.

Let us revisit the three primary applications for QT. *Quantum computing*, though the most publicized, is expected to significantly impact civil, defence, and security sectors on a more distant timescale of 10-20 years. *Quantum communication*, envisaged to become more relevant and applicable around 2030,



NATO has adopted the Technology Readiness Level (TRL) method of organizing technologies by maturity.



Quantum Applications show great promise across the electromagnetic spectrum.

promises secure and efficient data transmission. However, *quantum sensing and imaging* currently stand out for their immediate readiness, high interest, and profound near-to-medium-term military impact.

The average Technology Readiness Level (TRL) for quantum sensing systems ranges from 3 to 9, indicating that these systems have moved beyond basic laboratory testing and are demonstrating impressive results. Efforts are now concentrated on transitioning from laboratory environments to real-world applications while simultaneously reducing size, weight, power, and cost (SWaP-C) parameters. Recent years have seen significant demonstrations aboard ships, aircraft, and drones. Advances in integrated photonics, including integrating laser sources and miniaturizing vacuum chambers and atom/ion traps, are accelerating this transition, potentially hastening deployment.

In this paper, we delve into a detailed examination of several of the most impactful quantum technologies with a near-to-medium-term horizon. Each technology will be introduced with a brief overview of its workings, followed by an analysis of its advantages over current counterparts. We will then explore specific military applications, with a focus on the air and space domains, and conclude with projections on time expectations for these groundbreaking technologies.

Quantum-Enhanced Radars and Electronic Warfare

Quantum Radio-Frequency (RF) Sensing

Introduction: Quantum technology offers several promising approaches for RF sensing. Two notable technologies are those based on Rydberg atoms and Nitrogen-Vacancy (NV) centres, both applicable for narrow and wideband RF scanning and reception.

Rydberg atoms involve exciting an inner electron to high energy levels using finely-tuned lasers, turning the atom into a highly sensitive electric dipole. This sensitivity allows the atom to respond to specific RF signals based on the electron's energy level. The external RF field causes the electron to deexcite, emitting a photon in the optical domain for detection. The typical bandwidth of this method is around 10 MHz, indicating the potential need for a matrix of Rydberg-based sensors for wideband sensing.

Nitrogen-vacancy centres in diamonds are artificial defects in a diamond crystal lattice, formed by a nitrogen atom adjacent to a vacant lattice site. This structure yields a unique electronic state with an unpaired electron that can be manipulated and read. When a static magnetic field gradient is applied, the NV centres become sensitive to RF fields. Changes in the RF field affect the resonance in fluorescence, which is detectable optically. Unlike Rydberg-based technology, NV centres can handle bandwidths ranging from hundreds of MHz to a few GHz, depending on the magnetic field strength and gradient.

Advantage: Both technologies offer high sensitivity to electric (RF) fields, improved resistance to interference and jamming, self-calibration capabilities, and small sensor sizes (micrometres, irrespective of the measured wavelength).[1] They also boast broad tunability (from hundreds of kHz to hundreds of GHz) and resistance to strong electromagnetic (EM) pulses. Outputting in the optical regime allows for faster signal processing compared to traditional RF electronics. Both can operate at room temperature, though cooling can enhance sensitivity.

Their phase detection sensitivity is particularly noteworthy, enabling angle-of-arrival (AoA) estimates from sensors a few centimetres apart or even within one sensor.[2] Lest we get lost in the technical details, the practical application is profound: Accurate AoA measurement is essential for Electronic Warfare (EW) applications. Whereas traditional AoA measurement requires multiple sensors separated by larger distances for adequate accuracy, a quantum sensor can measure angle of arrival within 2° from sensors within centimetres of one another. This accuracy, combined with much smaller space requirements, opens many possibilities for hosting sensors on satellites, small UAVs, and many other platforms.

Applications: These technologies are suitable for wideband scanning, such as Signals Intelligence (SIGINT) and Communications Intelligence (COMINT). Rydberg-based sensors can form phase-sensitive arrays,with each sensor tuned to different frequencies for angle-of-arrival estimation.[3] NV centres, meanwhile, can function as a single sensor, although measuring higher frequencies requires stronger magnetic fields of around 1 Tesla for 30 GHz.[4] In comparison, an early generation magnetic resonance imager (MRI) in a hospital has about a 1T field. Fortunately, small electromagnets or permanent neodymium magnets can create such fields at the scale necessary for quantum applications, making practical deployment feasible. These quantum-enhanced EW units are versatile and suitable for deployment in jets, space surveillance, or as passive radar replacements/enhancements.

There's growing interest in Terahertz technology, which operates between 0.3 and 3 THz between the infrared and microwave regions, for new radar and communication applications. The Terahertz range offers very high data transfer rates with an estimated maximum of around 100 Gbit/s at 0.3 THz and unveils unique spectral patterns during material scanning in the THz range. Antenna sizes are small, but the detection range is short – just tens of metres due to strong atmospheric absorption. Fortunately, this limitation is not present at very high altitudes or in space. Rydberg-based sensors could be ideal receivers for such applications.[5] Moreover, narrow-band Rydberg-based RF sensing could simplify radar or communication receiver systems, applicable in LPI/LPD communication or future 6G technology.[6]

Prognosis: The initial deployment of quantum RF sensing technologies is anticipated to be ground-based, with ongoing research focusing on miniaturization for airborne and space applications. We expect these technologies to reach an initial field capability within three or more years.

Recent achievements in quantum RF sensing underscore this rapid progression. For example, Quantum Apertures, a project led by Honeywell, is developing a programmable wideband Rydberg-based sensor through DARPA.[7] This sensor demonstrates impressive capabilities, covering a frequency range from 10 MHz to 40 GHz, with a sensitivity of tens of - $nV.cm^{-2}.Hz^{-1}$, a one or two-order of-magnitude improvement over traditional systems. Such advancements can potentially

The disruptive effects of quantum technologies can change how we (and adversaries) design, defend, and attack telecommunication networks.

free up the crowded frequency spectrum and create the possibility of a whole new generation of frequency-hopping communications. The project started in 2021 and is expected to continue through 2026, showcasing the potential for these technologies in various applications. Furthermore, British Telecom (BT) has conducted notable tests in the context of 5G and IoT (Internet of Things) technologies.[8]

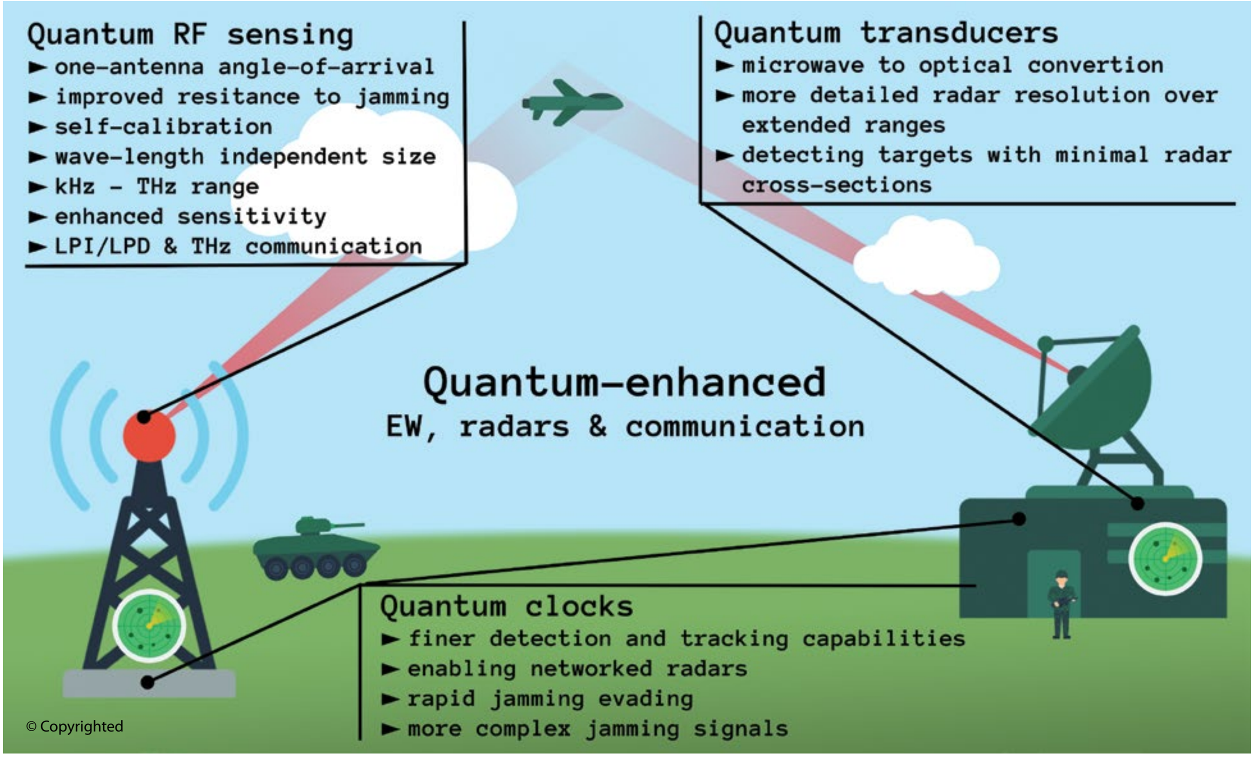
Quantum Clocks

Introduction: Quantum clocks, especially those based on optical lattice and trapped ion technologies, mark a substantial leap over traditional atomic clocks, entering the realm of ultra-high-precision timekeeping. Optical lattice clocks function by trapping atoms within a grid of laser beams, forming a lattice that maintains the atoms in a consistent environment, free from outside disturbances, such as the motion of adjacent atoms. This setup allows the atoms to oscillate at optical frequencies (~10^{15} Hz), which are significantly higher and more precise than the microwave frequencies (~10^{9} Hz) used in conventional atomic clocks.

Quantum logic clocks, on the other hand, confine single aluminium ions in electromagnetic traps. They utilize aluminium spectroscopy ions paired with a logic atom, typically magnesium. These clocks work by comparing the frequency of the two ion's vibrations after hitting it with a laser. The paired atom is then used to detect these vibrations (aluminium is exceptionally stable but has difficulty detecting its state). In terms of performance, optical lattice clocks excel in stability, while quantum logic clocks offer superior precision.

Advantage: Quantum clocks surpass traditional atomic clocks in precision and accuracy. The quantum logic clock, for instance, achieved a fractional frequency inaccuracy of merely 9.4×10^{-19} as of 2019.[9] This translates to a time deviation of only one second over more than 33 billion years, which is approximately three orders of magnitude more accurate than atomic fountain clocks.

Applications: Quantum clocks have two primary applications. Firstly, they are used for the distribution



Applications for Quantum Technology go far beyond quantum computing; quantum-enhanced devices have the potential to greatly advance capability while reducing vulnerabilities.

of precise time, such as in Global Navigation Satellite Systems (GNSS) like GPS. Secondly, portable, albeit less precise, quantum clocks are used for local measurements. One may still rightly ask why such extreme precision is useful. Such precise timing is crucial for various quantum sensing and measurement systems, ranging from quantum gravimetry and magnetometry to quantum inertial navigation and computing. Moreover, their enhanced precision can significantly benefit classical radar and electronic warfare systems.

For instance, GPS is accurate to less than 40 nanoseconds relative to Coordinated Universal Time (UTC); quantum clocks could refine this to the picosecond level. Additionally, incorporating a local atomic clock in GNSS receivers could bolster anti-spoofing capabilities.[10]

In radar systems, the extraordinary precision of quantum clocks allows for much finer detection and tracking capabilities. This is essential for identifying small, slow-moving objects, such as drones, at longer distances and even in cluttered environments.[11] Precise timing is also crucial for networked radars which combine multiple radar pictures in real time.[12]

For electronic warfare, integrating quantum clocks could transform communication and jamming strategies. Their ultra-precise timing enables military forces to rapidly change frequencies, evading enemy jamming. They also facilitate the transmission of more complex jamming signals to disrupt enemy communications or other EM signals. Furthermore, quantum clocks can be integrated into various military assets, enhancing accuracy and effectiveness.[13]

Prognosis: Quantum clocks are currently in the experimental stage, with ongoing development and refinement in labs. The transition to military deployment is expected to take some time, with commercial or military applications anticipated within the next few years. Experts are working on miniaturizing these clocks for integration into diverse military platforms, envisioning them to be compact enough for use in missile warheads, small drones, or electronic warfare pods on fighter jet.[14] For the air and space domain, the quantum clock could be relevant in 5 – 10 years. For example, optical clocks with a precision (relative uncertainty) of 10^{-11} within the 3U[15] package are already commercially available.[16]

Quantum Transducers

Introduction: Transduction refers to converging energy from one form to another, such as antennae, microphones, and accelerometers. However, microwave-to-optical signal conversion is a transduction process that is just now available thanks to quantum transducers, which are pivotal in transferring (quantum) information from the microwave domain to the optical regime. These transducers employ various mechanisms, such as electro-optical and magneto-optical devices, opto-mechanical structures, and atoms with appropriate energy level spacings, to facilitate coherent signal conversion. Recent progress has notably enhanced their efficiency and bandwidth. For example, efficiencies nearing 80% have been reported.[17]

Advantage: Converting microwave signals to optical frequencies via quantum transducers offers distinct advantages over traditional microwave signal processing. This conversion enables the mapping of information from a narrow-bandwidth microwave field to a broader optical frequency range. This capability is crucial for coherent frequency-division multiplexing (FDM), which enables the simultaneous processing of multiple signals within the optical domain rather than relying on several parallel microwave channels. This leads to improved efficiency in complex signal-processing tasks.[18]

An additional advantage relates to environmental influences. At room temperature, the optical domain is characterized by minimal photons from thermal noise. This is a significant advantage over microwave frequencies, where thermal-photon occupation can introduce noise in signals. Optical domain systems have also shown proficiency in phase-correlated amplitude control of the multi-channel optical field, akin to a frequency domain beam splitter. This enables precise control over specific frequency channels, facilitating rapid filtering, signal processing, and more efficient digitalization.

Applications: In radar technology, quantum transducers can substantially enhance performance. By converting microwave signals to optical frequencies, these transducers allow radar systems to achieve greater sensitivity, particularly in detecting targets with minimal radar cross-sections and weak return signals. Optical frequencies provide wider bandwidths and higher frequencies, resulting in more detailed radar resolution over extended ranges.[19]

Quantum Transducers have applications across the spectrum of radar receivers, including in photonic-microwave radars, electronic warfare systems, and remote sensing and surveillance. The amalgamation of microwave robustness and optical frequency resolution significantly bolsters the capabilities of various sensing technologies, essential for the next generation of comprehensive surveillance and intelligence gathering.

Time Expectations: Integrating quantum transducers into military applications is anticipated to be progressive. With current advancements in quantum technology, we can expect prototypes to emerge within the next five years. For instance, the development of integrated quantum transducers for quantum computing applications is already underway.[20]

Conclusions

This article delves into the realm of quantum technologies, highlighting their expanding significance and immense potential within the military domain, specifically in the areas of radars and electronic warfare for air and space operations. Quantum sensors already show high levels of technological readiness, and their application in diverse and challenging military environments appears close. These advancements are not just theoretical; practical demonstrations in real-world scenarios aboard ships, aircraft, and drones highlight the transition of these technologies from laboratory settings to operational fields. Such advancements will also be further examined in the third article in this series, focusing on intelligence, surveillance, and reconnaissance (ISR), and positioning, navigation, and timing (PNT). ●

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Assessing the Viability of Electrically Powered Flight in Military Operations

By Major Eelco Tolsma, NE Air Force, JAPCC

Introduction

The trajectory of climate discourse has evolved dramatically over the years, reflecting the growing urgency of the situation. From the initial fears of global cooling in the 1970s to the subsequent shift towards global warming in the 1980s, the narrative has now evolved into the broader concept of climate change. However, the gravity of the situation has escalated even further in recent years, leading to the recognition of a full-blown climate crisis in the 2010s. Today, we find ourselves in the midst of a climate emergency. The message is clear: something has to happen.

How can we try to reverse things? Without a better alternative, the consensus seems to be to electrify 'everything'– electrification is seen as the Holy Grail to save the climate.

But electrification is not as new as one might think – as early as 1828, society started to experiment with electric transport. Initially, it began with scaled-down versions of modified carriages, and the first full-scale 'car' was realised in 1888. The so-called 'Flocken Elektrowagen' was a German-built carriage powered by an electric motor with a lithium battery.

Figure 1: *The world's first electric car, the German-built Flocken Elektrowagen.*

Electric cars are not as new as one might think. How about electric powered flight, then? That idea also goes back surprisingly far. In the 1880s, two French army officers, Charles Renard and Arthur Krebs, put huge batteries combined with an eight-horsepower electric motor in a hydrogen-filled balloon to enable it to do what no balloon had done before: return to its launch site at the end of a flight.

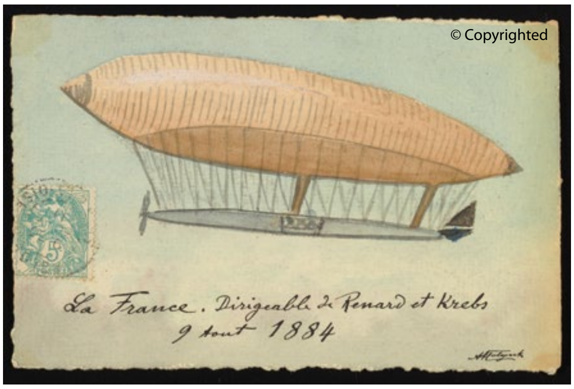

Figure 2: *Renard and Krebs' electric balloon, the first to return to where it started from.*

However, despite this early triumph, there was no follow-up for about 90 years. Only in 1969, did brothers Bob and Roland Boucher start the current evolution by using electric motors for model aeroplanes. The seed was planted, and we are now in an era where much more is technically feasible regarding the electrification of flight. It truly is electrifying…

To fight the climate crisis, there is a growing push from the public and national and international regulators towards electrification in both earthbound and aerial transportation. Electric Vehicles (EVs) are becoming more common on the roads, and many countries are setting targets to phase out the sale of new gasoline- and diesel-powered cars. Similarly, the industry is developing and testing electric aircraft with the aim of reducing emissions and increasing efficiency. This is the time where the military world must jump on the bandwagon and come up with workable solutions for their part of the energy issue. Although the emphasis in the industrial world is on electrification, we should not rule out other options, such as synthetic fuels, biofuels, and hybrid systems, while maintaining a guaranteed energy supply to maintain operational flexibility and effectiveness.

Military Aspects of Energy Security

Military operations require enormous amounts of stable, reliable, and continuous energy, no matter the form, making it a critical enabler for NATO forces' operations and logistics. However, it comes at a price:

> *'Recent operations and growing environmental concerns have highlighted security challenges related to the extensive use of fossil fuels; it is not only a financial issue, but it also increases operational vulnerability of military forces and endangers environmental sustainability. Climate change is military-spoken a threat multiplier, affecting every military operation. It could (and most likely will) affect military capabilities and strengths and with that, the possible outcome in a crisis.'*[1]

If the military world were to be cut off from its energy supply, everything would come to a standstill.

Aviation Emissions

As expected, aviation is an active contributor to global greenhouse gas emissions. NATO alone burned roughly 250 million litres of jet fuel per day in

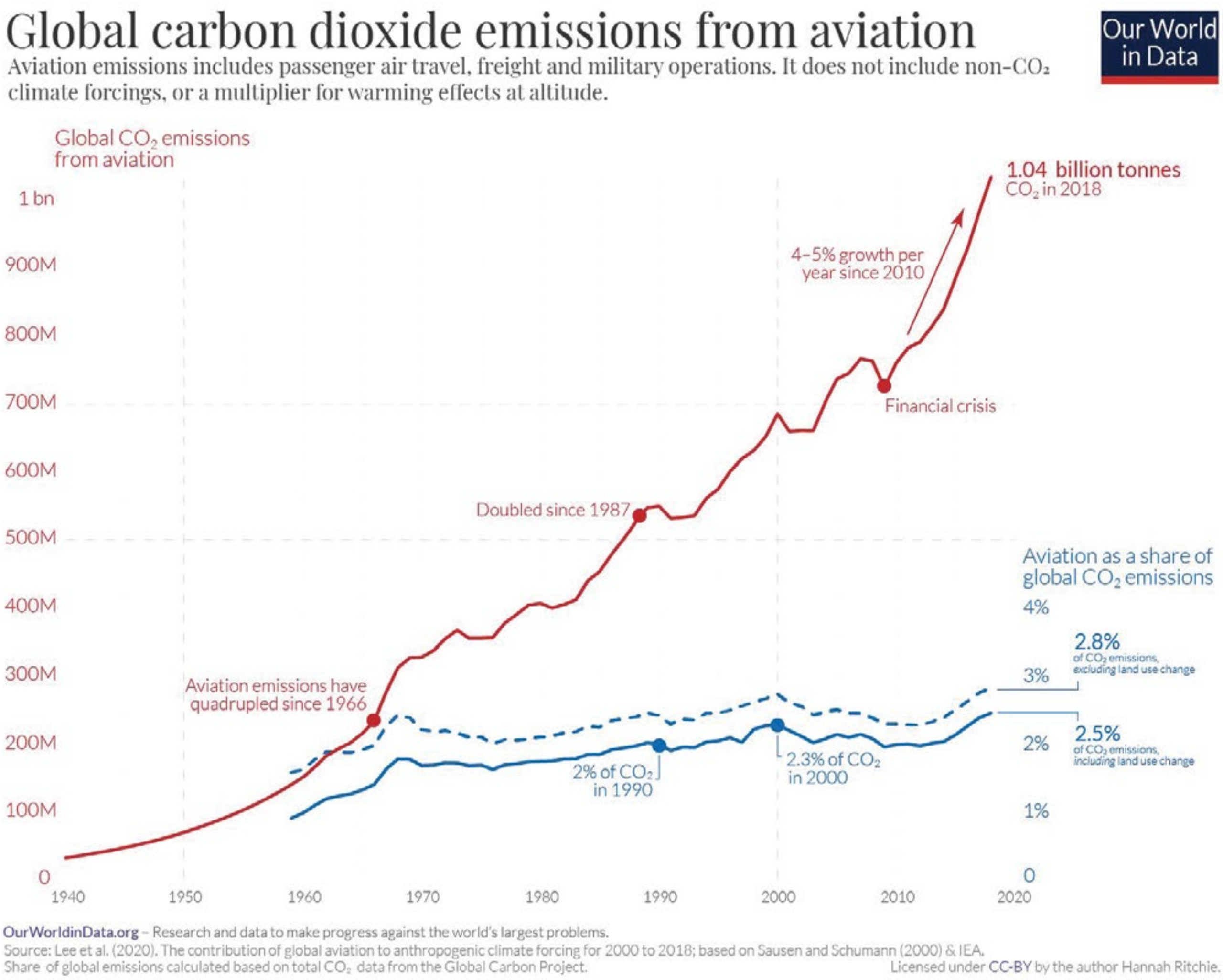

***Figure 3:** The above figure includes CO_2 emissions from all flights, including international and domestic passenger flights, cargo, and military flights.*

2022, and according to the International Energy Agency (IEA), the aviation sector accounted for approximately 2.5 % of global CO_2 emissions in 2019. This looks like a small proportion, but when emissions from other sources associated with aviation, such as nitrogen oxides (NO_x) and contrails (both can cause trapped heat in the atmosphere) are considered, the total warming effect of aviation is estimated to be 2–4 times higher than the warming effect of CO_2 emissions alone.[2]

Although aviation emissions are a relatively small percentage of total emissions today, their impact is significant and is expected to grow.

Energy Density

An important point to note for any flight is the amount of usable energy, retrievable from the type of combustible, known as the energy density, expressed in Mega joules per kilogram (Mj/Kg). The higher the energy density of the combustible, the more energy may be stored or transported for the same mass.

Energy density indicates how much 'positive' is for the 'negative'. The positive could be explained as flight time, payload, range, etc., and the negative as weight, volume, fuel consumption or other adverse effects on the operational use of an aircraft. For now, liquid

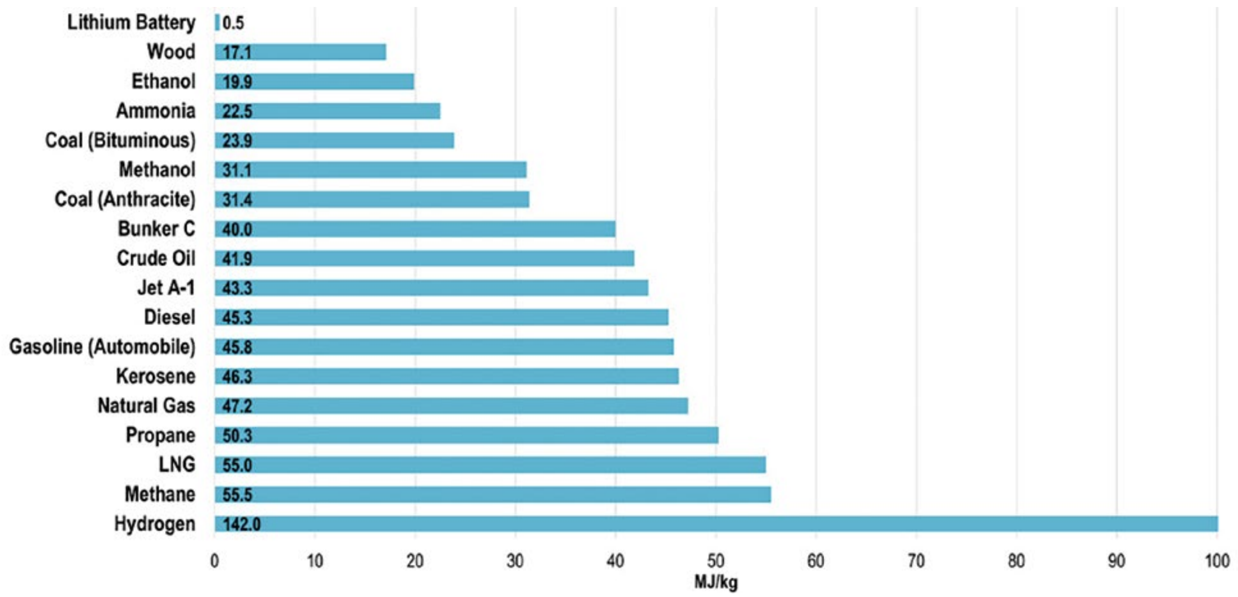

Figure 4: *A comparison of the Energy Density of Common Combustibles, expressed in Mega Joules per Kilogram. The higher the number, the more usable energy relative to its mass.*

hydrocarbons, such as gasoline, diesel, and kerosene, are still the densest way known to economically store and transport chemical energy at a large scale.[3] In comparison, jet fuel has an approximate energy density of 43Mj/kg,[4] while the highest performing Lithium battery, possesses approximately 1Mj/kg.[5] This is a significant difference, and although an electric motor is more efficient than an internal combustion engine in transforming stored energy into mechanical energy (see below figures), the weight of the batteries needed to store the same amount of energy as in kerosene is still very high.

Fortunately, researchers are constantly improving battery technology, and breakthroughs will make it possible to develop more powerful and lightweight batteries in the future. The solid-state battery, which uses a solid electrolyte instead of a liquid, has a higher energy density, which looks promising.

The Elephant in the Room

Battery technology has yet to reach a point where it can safely provide the same energy density as traditional fossil fuels. Getting an acceptable range from current battery technology requires a bulky and heavy storage system, including a temperature-regulating system for safety and efficiency. Furthermore, there is the issue of battery energy output versus ambient temperature. Low ambient temperatures cause a battery to perform less than at high ambient temperatures, which could cause significant operational limitations when operating in colder areas. Although high temperatures may positively affect the battery output, it will negatively affect the battery's life cycle and internal temperature, which might build to the point of self-combustion.

Several strategies can be employed to mitigate the weight issue. One approach is to use more lightweight materials and designs to reduce the weight of the rest of the aircraft, and although this will increase cost, it might also be beneficial for use on current military aircraft. One could also make use of unmanned flight, where you replace personnel and non-essential equipment with batteries. This can offset some of the batteries' weight and improve the aircraft's overall endurance. Both strategies have implications that may be a bridge too far for the military now, but it is certainly

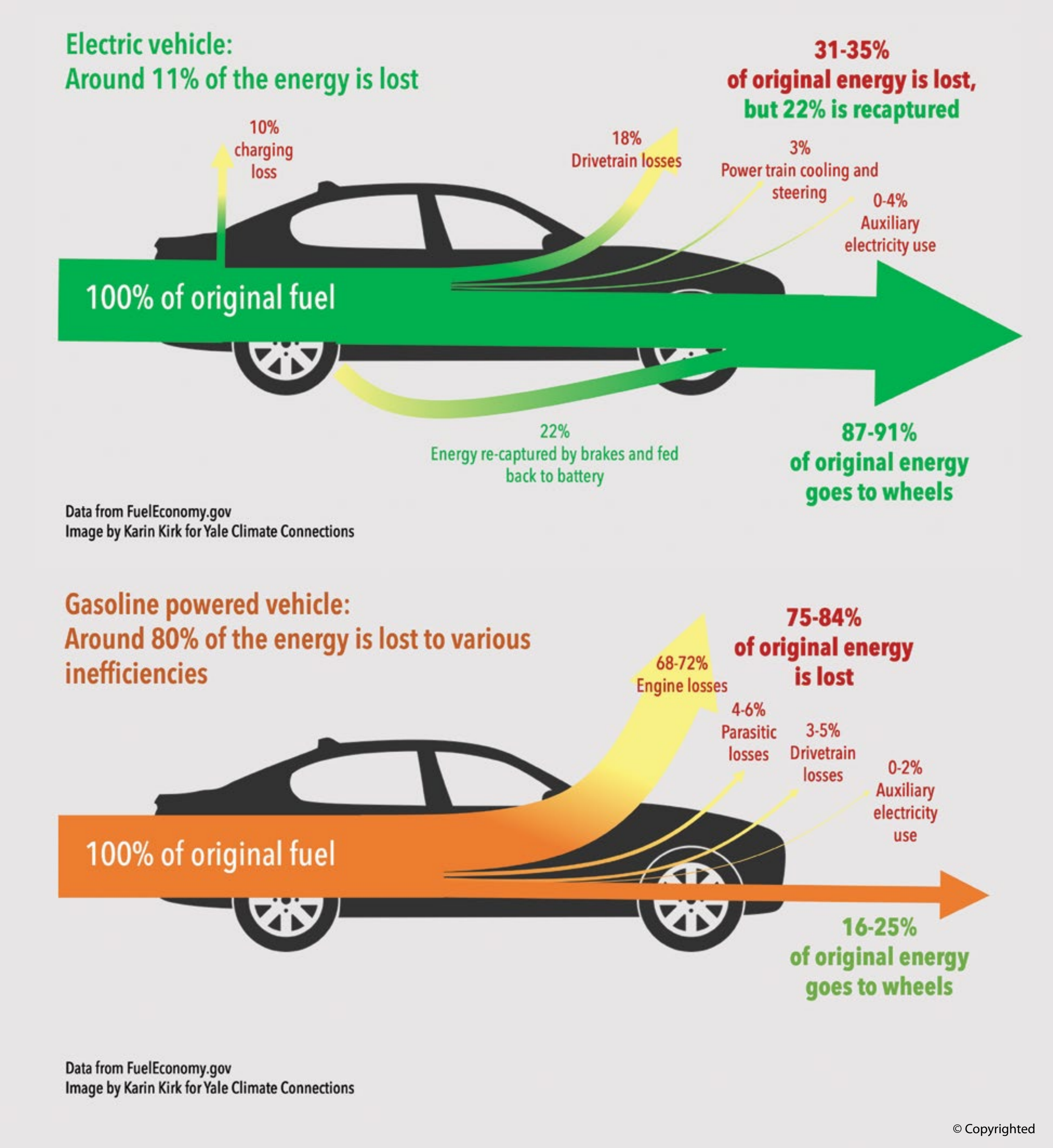

***Figure 5:** Electric-powered vehicles are far more efficient than internal combustion engines. This advantage is partly offset by the large size and weight of the battery.*[6,7]

worthwhile to further investigate the possibilities, positive effects, and military implications.

Apart from the energy storage challenges associated with electric helicopter flight, the logistical support could also present some challenges. Batteries require a charging infrastructure that can provide high levels of power, and this infrastructure may not be widely available or easily accessible in all locations, either when replacing an emp-

***Figure 6:** Artist's impression of a possible electric military helicopter in the future*

ty battery with a full one or charging on site. Furthermore, the charging time for batteries is longer than the refuelling time for traditional fossil fuel-powered aircraft, which could impact mission readiness and turnaround times. And lastly, the weight and expected high cost of replacement batteries due to airworthiness requirements will affect the supply chain.

However, it's important to note that these challenges are not insurmountable, and the electric aviation industry is working to address them. For example, there are efforts to develop charging infrastructure that is more portable and can be easily transported to remote locations.[8]

Are There Positives?

For years, the industry has been working on hybrid-electric aircraft for commercial use, and they are making good progress.[9] For example, New York City had its first demonstration flights with electric vertical take-off and landing (eVTOL) aircraft in November 2023, and Japan's national airline ANA is aiming for commercial eVTOL flights starting in 2025. The industry recognizes the potential.

The electric drive train knowledge acquired in these commercial applications is beneficial for developing electric military aircraft. In addition to the environmental benefits of electric flight, it has the potential to provide significant military benefits. The absence of smelly emissions, reduced noise levels and heat signatures (less trackability) and less sensitivity to flammability/explosiveness when under fire are highly desirable properties for military operations. In addition, electric aircraft will have fewer and simpler drivetrain components, such as batteries and electric motors, compared to currently used aircraft that require fuel tanks, internal combustion engines, gear-boxes, and axles, thereby reducing the number of components that can fail, potentially improving reliability. Aviators would benefit from this, and the supply chain for spare parts would be less stressed than for traditional aircraft.

This will have a positive impact on maintenance, repair activities, employability, and sustainability.

Near Future

While it is difficult to predict the exact timeline for adopting electric flight in the military, there are some promising signs of progress.

For example, within the Joint Capabilities Group Vertical Lift (JCGVL), the US Department of Defense is looking into the possibilities for an all-electric helicopter intended to provide improved speed, range, and agility compared to existing helicopter designs. Furthermore, the Slovenian and Danish Air Forces are evaluating the Velis Electro as a basic pilot training aircraft.[10] Also, the United States Air Force has conducted its first manned electric flight with an eVTOL with military airworthiness.[11]

The aviation industry is becoming more focused on reducing emissions and improving sustainability, which could drive greater investment and innovation in (military) electric flight technology. In the meantime, using synthetic fuels, biofuels, or hydrogen fuel cells can be an interim solution to the climate problem.

Synthetic fuels, also known as e-fuels, are produced using renewable energy sources such as solar or wind power to produce hydrogen, combining this with carbon dioxide captured from the atmosphere or industrial processes.

Biofuels produced from renewable sources such as algae or agricultural waste reduce greenhouse gas emissions compared to traditional jet fuels since they burn cleaner and are more carbon neutral.

Hydrogen fuel cells, which produce electricity through a chemical reaction between hydrogen and oxygen, have also shown promise as a potential power source for aircraft.[12]

Conclusion

With a world adapting to the changing climate and where electrification of transport can contribute to reducing greenhouse gas emissions, the military sector will have to conform under the influence of public opinion and national and international regulations. With regard to the effective use of military electric aircraft, there is still a long way to go, but there are also benefits to be achieved. Apart from the environmental advantages, electric aircraft also have the potential to offer significant military advantages such as reducing emissions, noise levels, and heat signatures, and being less flammable/explosive under fire.

Unfortunately, electric aircraft face several significant technical challenges, particularly in terms of battery technology and weight/range limitations. While there have been some recent advances in battery technology, batteries are still heavy and have limited energy density compared to traditional fuel sources. For now, electric aircraft have more limited range, endurance, and load capacity than traditional aircraft. Although there are challenges associated with achieving operationally viable electric aircraft as a substitute for fossil fuel aircraft, overcoming these challenges over time is possible. There are ongoing developments in battery technology, charging possibilities, material composition, autonomous flight systems, and other AI-powered technologies that could help address some of the key limitations of military electric helicopter flight. It is up to the military to set the requirements and to industry to innovate and develop the necessary techniques. In the meantime, to address the climate issue, the military could use interim solutions such as the use of synthetic fuels, biofuels, and hybrid drive.

Transitioning to new energy solutions and, ultimately, electric drive is not an easy task and will undoubtedly impact how operations are conducted. But based on the advantages, combined with the current pace of developments and the perceived necessity for cleaner aircraft, it is likely that electric aircraft will play an important role in military operations in the years to come. To continue to ensure the employability of any nation's armed forces, it is a transition effort that every country should already be working on. ●

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A Boeing E-7 Wedgetail in flight with its active electronically scanned array radar.

Alliance Future Surveillance and Control (AFSC)

How Will NATO Continue to Effectively Monitor the Skies?

By Major Patrick Giesenfeld, GE Air Force, JAPCC

Introduction

The NATO E-3A, or AWACS (Airborne Warning and Control System), had its first operational mission in 1982. This remarkable aircraft has the ability to track and detect airborne threats from hundreds of miles away, while simultaneously commanding and controlling friendly forces. Throughout its four decades of service, the AWACS has undergone numerous upgrades to its mission and flight decks, sensors, and communication systems.[1] Despite this highly successful service record, continued use of these aircraft faces additional challenges. One of the primary obstacles lies in the realm of maintenance. As time progresses, the task of maintaining these aircraft becomes increasingly arduous. The scarcity of spare parts, which are often no longer produced or available, exacerbates this issue. Consequently, the already meticulous management of flight hours is resulting in a gradual reduction each passing year.

NATO currently has a fleet of 14 Boeing 707 type AWACS aircraft, stationed in Geilenkirchen, Germany.[2] However, the operational number within the fleet is

NATO aircrew prepare to take off in their E-3A Airborne Warning and Control System (AWACS) aircraft at Šiauliai Air Base in Lithuania.

decreasing considerably. The scarcity of maintenance personnel further compounds the problem, as they grapple with an escalating array of challenges in ensuring the aircraft remain serviceable. In many instances, aircraft are cannibalized for spare parts to sustain the better-maintained ones in the fleet. Nevertheless, technical issues are not the sole hurdle that must be overcome.

In times of worldwide conflict, interoperability and fast data processing are vital, and current systems are struggling to keep pace with the speed of development. To handle the ever-increasing amount of data and information, new technologies may need to be introduced and exploited, such as Big Data Management, Unmanned Aircraft Systems (UAS), Emerging Disruptive Technologies (EDT), Artificial Intelligence (AI), and Machine Learning (ML). In response to these challenges, NATO is already developing a programme for a modern, interoperable, capable, and reliable System-of-Systems (SoS) to ensure the Alliance's future surveillance and C2 needs for 2035 and beyond. This programme is called Alliance Future Surveillance and Control (AFSC). However, recognizing the pressing need to address the current gap, multiple NATO nations have made the strategic decision to accelerate the deployment of an already established platform – the Boeing 737 E-7A AEW&C Wedgetail. This move serves as a crucial component towards achieving the eventual AFSC SoS.[3] This platform should only represent one aspect of the envisioned AFSC capability requirements, as the remaining components of the programme will need to progress in a complementary manner, albeit on their own timeline. Collectively, these approaches beg the question: Will NATO be able to fuse all the development paths and have a coherent solution in the end?

The Need for a New Capability

In the Warsaw Summit Communique of 9 July 2016, NATO heads-of-state declared that by 2035, the Alliance would need to have a follow-on capability for the E-3A NATO AWACS.[4] In order to keep up with modern airframes and technologies, and to maintain operational effectiveness, the Alliance has acknowledged the necessity for a new capability to fulfill NATO's primary Command and Control (C2) functions, as outlined in the Framework for Future Alliance Operations (FFAO).[5] Consequently, the communique established AFSC with the purpose of addressing the limitations of the E-3A and ushering in a new era of advanced surveillance and control capabilities. NATO Secretary General Jens Stoltenberg stated, 'AFSC is the biggest investment programme of NATO ever to replace the phasing-out of AWACS in 2035'.[6] The aim was to completely redefine how NATO conducts surveillance and C2 in the future.

With the AFSC programme, NATO has already taken a first step towards the future. Significant changes to former operations must be made to fulfil NATO's goal of having AFSC in service by 2035 and to operationalize NATO's new strategic and operational concepts. The new operational requirements underlining the AFSC programme match those defined in the new Multi-Domain Operations (MDO) concept.[7] As a significant evolution of joint operations, MDO started when the Alliance formally recognized cyberspace and space as domains. This recognition was accompanied by the emergence of a challenging new operating environment, marked by the rise of threats such as A2/AD, hybrid warfare, hypersonic weapons, and adversaries' exploitation of EDTs. To effectively address the aforementioned challenges, NATO needs to simultaneously operate in all five operational domains (air, land, maritime, space, and cyberspace) to achieve converging effects at the speed of relevance. Generating a real-time or near real-time common operational picture, shortening the OODA loop, connecting every sensor to the shooters in the fastest possible way, and implementing a cross-domain command capability are the new challenges for AFSC in the MDO environment.

By design, AFSC is not a one-to-one replacement for the AWACS and is intended to be platform agnostic. It is, instead, a SoS based on the MDO approach. As such, the overall AFSC Technical Concept is for an integrated, state-of-the-art, dynamic, adaptable, and federated SoS. This concept is characterized by a resilient, scalable, and flexible distribution of tactical control, battle management, and surveillance functions across its constituent systems, to support a wide range of military requirements across all operational domains and the range of military operations. Currently, NATO considers available surveillance and control assets, evolving surveillance platforms, communications systems, cyber warfare, and cloud computing functions as the key elements of the AFSC.[8] In a military context, the programme refers to integrating various military platforms, technologies, and subsystems to create a comprehensive and interconnected network that enhances military capabilities and effectiveness. AFSC recognizes that modern warfare cannot be effectively addressed by individual structures alone. Assets integrated into AFSC can include fighter aircraft, ground forces, naval vessels, satellites, UAS, communications networks, intelligence data, and more. By integrating these systems, NATO achieves improved situational awareness, distributed C2 capabilities, and cross-domain functions.

'The AFSC Technical Concept is characterized by a resilient, scalable, and flexible distribution of tactical control, battle management, and surveillance functions across its constituent systems, to support a wide range of military requirements across all operational domains and the range of military operations.'

With the development of a project like AFSC, a very long list of challenges and requirements need to be considered. For maintenance, specialist personnel are rare and must have proper training. Also, the new airframe portion of the AFSC needs to be stationed in tactically favourable regions. These should be central enough to be immediately employed in support of Allied forces in every theatre all over the world, but also not too close to possible threats. Additionally, there is an urgent need for reliable surveillance and control in all five domains, as well as the ability to operate in complex situations as already seen in Ukraine and the Middle East. The new capability must take into consideration the need to also share information with non-NATO entities and partner nations. The system must deliver the right information, to the right place, at the right time.

To always be one step ahead of the opponent, NATO must strive for information dominance. To this end, connectivity is a very important prerequisite for interoperability, which is, in turn, the prerequisite for shared awareness. Moreover, AFSC must have improved system characteristics relative to AWACS to support time-sensitive decision-making. Commanders must be able to identify and retrieve needed information as easily and comprehensibly as possible. AFSC requires the development of standardized communication protocols and data exchange formats. Interoperability can be significantly improved by establishing seamless integration and information sharing between different systems from the beginning. Considering how rapidly crises and conflicts can unfold, decision-making processes will need to be swift, whilst maximizing the commander's ability to delegate authority where applicable. Furthermore, the AFSC programme envisions continued research and development through collaboration with industry partners, academia, and allied nations, and must also build flexibility for unknown future innovations.

The Evolution of AFSC

In 2021, NATO invested over one billion euros in the Final Lifetime Extension Programme (FLEP) to extend the AWACS programme until 2035, leaving enough time for the build-up of AFSC. FLEP includes several upgrades for AWACS, but these are limited to communication, operator systems, and link capabilities.[9] The airframe, the biggest liability concern, was not and will not be upgraded.

The AFSC project is composed of three Stages (Pre-Concept, Concept, and Development) which, in turn, have several phases.[10] Stage one was about defining the project, prioritizing the requirements, and getting was industry involved, and was completed in 2018. It included the development of the AFSC Capability Architecture, the development and refinement of the AFSC Capability Requirements, a gap analysis, and studies in preparation for the next phase. Currently, the initiative is in Stage two, the Concept Stage, which consists of three phases.

Phase two included High-Level Technical Concept (HLTC) studies and in-depth analysis of derived products with the Risk Reduction and Feasibility Studies (RRFS). The RRFS were conducted over a period of one year and resulted in a significant amount of technical information provided by industry on potential technologies and systems concepts that could meet the AFSC Capability Requirements. Industry studies conducted in phase two aimed to understand the availability and feasibility of potential industry solutions to fulfil the AFSC Capability Requirements whilst addressing the future technologies and operating environment by 2035, and beyond.

'AFSC is the largest and most complex capability programme NATO has collectively undertaken to date. NATO's analysis identified that no single industry concept would meet all capability requirements for AFSC by 2035 across the range of military operations.'

In phase three, the final phase of the Concept Stage, capability targets will be established to fulfil the selected AFSC Technical Concept and to develop and procure one or more materiel solutions through the stages that follow. Phase three will include an AFSC capability review to identify available or planned national or NATO elements that could contribute to the AFSC SoS and meet the AFSC Technical Concept and operational requirements. The results will inform the development of NATO Defence Planning Process (NDPP) Capability Targets, as well as the programmatic arrangements necessary to mitigate potential gaps. Stage two is planned to be completed in 2025.

In the third stage, development, NATO must develop the full slate of capabilities necessary to realize the complete AFSC concept. The development will last until 2035, through a combination of jointly funded multinational groups, and individual nations' contributions. The concept foresees an open architecture in a federated approach, with cross-domain functionalities tailored to the mission and understood as a web of connected capabilities. These capabilities will be a mix of NATO, multinational, and national ones. The project also must ensure coherence between the AFSC and the future NATO Air Command and Control (AirC2) structure. Another challenge is that AFSC must also link to existing capabilities, like national C2 sites, AEW&C sensors, and fourth up to sixth generation air platforms. All of these capabilities should be freely adaptable, customizable, and configurable to suit the mission, rather than being confined to a single platform.

In November 2023, the NATO Support and Procurement Agency (NSPA) announced its acquisition strategy for an initial Alliance Future Surveillance and Control (iAFSC) capability.[11] Based on a US Foreign Military Sales (FMS) case, NSPA intends to acquire six E-7A Airborne Early Warning and Control (AEW&C) Wedgetail aircraft manufactured by Boeing.[12] This consortium, consisting of seven Support Partnership Nations (Belgium, Germany, Luxembourg, the Netherlands, Norway, Romania, and the United States) along with the NSPA, concluded that the Wedgetail is the only known currently available system capable of fulfilling the strategic commands' essential operational requirements in the short term. This capability must be considered as an initial solution to eventually support the overall AFSC. The NATO Wedgetail is expected to reach Initial Operational Capability (IOC) in 2031.[13] An airframe the size of the still-flying AWACS certainly plays a role in deterrence by its pure appearance and could be employed in strategic messaging. However, this single platform is not enough if we want to achieve all the capabilities envisioned in the original AFSC programme.

Implementing AFSC into NATO Strategies and Doctrines

The development of AFSC, with many of its capabilities and implementation still in the future, needs to be in line with and support existing doctrines and strategies of the Alliance. It also needs to satisfy the operational requirements defined in current and future NATO concepts, plans, and processes. Some, for example, include the NATO Warfighting Capstone Concept (NWCC), the MDO concept, and the NATO Defence Planning Process (NDPP). In particular, the NDPP aims to provide a framework within which national and Alliance defence planning activities can be harmonized, enabling Allies to provide the required forces and capabilities most effectively. Through the NDPP, NATO identifies the capabilities that it requires and promotes their development and acquisition by Allies. The NDPP consists of five steps (Political Guidance, Determine Requirements, Apportion Targets, Facilitate Implementation, Review Results) conducted over a period of four years.[14] The next cycle will start again in 2024, which means that AFSC should be incorporated into the next NDPP cycle to make sure that identified capability targets can be developed over the remaining two cycles before 2035.

Doctrines and planning processes will give the AFSC project the guidance needed for its further development. For this reason, nations and industry will have the challenge of keeping such a long and ambitious project current and in line with a constantly changing operating environment, which in turn affects NATO's posture and vision. But not only political influence and economic requirements will play a role. Implementing AFSC in NATO's strategic planning for the next decade and beyond will demand close monitoring and supervision in project management to ensure it reaches all important preset milestones. The configuration (links, radios, sensors, etc) of the iAFSC should be developed following the results of the requirements defined for the original AFSC SoS to guarantee integration. The capability development phase for both iAFSC and AFSC segments needs to be in close coordination between all parties involved. This means especially that industries and companies involved must work together, without 'boxing out'

In coordination with the NATO Support and Procurement Agency, a seven-nation consortium is acquiring the Boeing E-7A Wedgetail as an interim solution on the path to a holistic AFSC system-of-systems.

each other. Harmonizing such disparate but complimentary efforts is a great challenge. NATO should establish common monitoring and controlling phases to ensure interoperability exists between all systems.

Conclusion

The NATO AWACS has been operational for over four decades now. Although communications systems and operational parts like sensors and flight decks have been upgraded, the airframe itself is still the same. As of today, the AWACS capability is presenting a mix of challenges ranging from a smaller fleet to decreased operational readiness, and logistics and personnel shortages. All these factors represent an operational gap when compared with NATO's current level of ambition. So, a new capability for the command and inform military functions is one of the most urgent operational requirements for the Alliance.

With the recent decision to procure six E-7A Wedgetail Airborne Early Warning and Control (AEW&C) aircraft, NATO has wisely decided to lower the risk of not having a capability ready to replace the AWACS by 2035. In other words, the Alliance has decided to give priority to a tangible and concrete answer to the operational gap described above. The approach also recognizes the benefits of economies of scale, commonality, and interoperability derived from multinational acquisition of off-the-shelf military platforms.

AFSC is the largest and most complex capability programme NATO has collectively undertaken to date. NATO's analysis identified that no single industry concept would meet all capability requirements for AFSC by 2035 across the range of military operations. Even though the Wedgetail represents a suitable 'interim' solution, NATO nations must make sure that they do not lose the momentum generated by the AFSC SoS concepts, which represent much more than a stopgap. The iAFSC acquisition must be considered as just a portion of the original ambitious vision of AFSC. The new challenges will be represented by the need for strong cooperation across industries, to make sure that the iAFSC airframe will be integrated within all the other systems envisioned in the original AFSC SoS. The AFSC project has large potential to operationalize C2 in MDOs and operate successfully in complex future environments around the globe. ●

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Allied Air Command Lessons from Ukraine: Implications from NATO Air & Space Power Conference

By Wing Commander Joe Goodwin, UK Air Force, HQ AIRCOM

The presence or absence of air superiority will continue to determine the entire character of conflicts; achieving air superiority requires much more than just fighters.

Introduction

The ongoing conflict between Russia (RUS) and Ukraine (UKR) has presented a unique opportunity for the Alliance to reflect on the experiences of both combatants and extract significant lessons for both the Air and Space domains. Whilst there has been extensive coverage of the conflict in the media, objective examination of the Air and Space Domain has been harder to come by. To inform the significant work within the Alliance aimed at addressing evolving European security dynamics, Allied Air Command hosted a conference in June 2023 supported by national think tanks, academic institutions, and defence academies – an audience of over 200 personnel with representation from across nations and components.

This article aims to offer initial assessments, consider implications for NATO Air and Space Power, and offer lessons that can be applied across the Alliance, the most notable of which is the failure of either RUS or UKR to achieve air superiority, and the consequent attritional land-focused conflict that followed. It will consider the effectiveness of RUS's Air and Space operational design, the consequences of the VKS's (RUS tactical air force) failure to embrace the requisite level of training/integration in the 20 years preceding the invasion, and offer an analysis of RUS resilience and a basis of assumptions for the future. It will review key tactical threats posed by RUS and the associated challenges for NATO to achieve the correct balance between 'exquisite', high-performance weapon systems versus the mass of cost-effective 'precise enough' munitions to counter near-peer adversaries. It will consider more universal, contemporary challenges, including the democratization of key technologies and the pervasiveness of the information space. Finally, it will examine the key tenants which have enabled UKR to survive and operate against what were almost universally considered to be unbeatable odds.

Air Superiority Remains Job #1

'Neither side was able to achieve sustained Air Superiority and if you don't have freedom of movement in the air, you don't have it in the land or maritime domains either.'[1]

Lack of air superiority has meant each side is reliant on their Integrated Air Defence Systems (IADS) for defence from air attack, with UKR more reliant than RUS due to Moscow's advantages in both the number and quality of their fixed-wing aircraft and long-range stand-off strike capabilities. RUS's failure to exploit these advantages should not obscure the credit which is due to UKR. The IADS with which UKR began the war was far denser, more extensive, connected, and coordinated than that protecting any comparably sized area of NATO territory, and this IADS has arguably only improved (despite massive expenditure of missiles) with the addition of modern Western Surface Based Air Defence Systems (SBADs), Anti Aircraft Artillery (AAA) and other systems.

Failure to achieve air superiority has forced both sides into fighting a prolonged land-focused attritional conflict. This is particularly noteworthy for the prolific use of artillery and the resulting mass destruction of civilian areas which would not be politically acceptable for the West. Had RUS been able to achieve air superiority at the start of the campaign, the situation UKR finds itself in today would have been markedly different.

Key Considerations:

- Contesting and denying the Air Domain remains priority #1 for the air component; it is crucial to enabling all defensive and offensive activities across the 'physical' domains.
- Counter-Anti-Access/Area Denial (A2/AD) and physical destruction (Destruction of Enemy Air Defences – DEAD), not just Suppression of Enemy Air Defences (SEAD), should be an essential focus for NATO multi-domain operations.
- In contested space, we will not have the unfettered air superiority we were accustomed to in Counter-Insurgency (COIN) operations. Adjusting our approach, with an ability to achieve localized and temporary air superiority to enable intermittent friendly air 'access' may be more realistic.
- Additional investments in a multi-layered, cost-effective Integrated Air and Missile Defence (IAMD) capability, able to match the most appropriate weapon to the target is crucial to securing an effective A2/AD capability across NATO territory.

Future Adversaries May Not Repeat RUS's Mistakes

'Although Allied intelligence overestimated RUS Air and Space operational design, the RUS systems which worried us before the conflict should still worry us today; RUS will reconstitute and apply hard earned lessons from this conflict'. [2]

RUS's Air and Space operational design, influenced by their intelligence failings which underestimated UKR capability, failed to effect the plan to seize control of Kyiv and UKR. The planned invasion included massive stand-off weapon strikes against Command and Control Air Defence (C2AD) targets, deep SF/VDV (RUS airborne troops) helicopter insertions to seize key terrain, and was expected to take three days. It was both a failure in concept and execution. RUS's reliance on pre-planned strikes failed to account for the inherent mobility of UKR's air defences, with battle damage assessment (BDA) and the targeting cycle being far too slow. The mistakes and delays on day one likely led to the failure of the operation – an example here being the key failure to capture and secure Hostomel Airport.

RUS squandered a crucial window of opportunity when UKR was unprepared and foreign backing for Kyiv largely non-existent. RUS airpower has continued to struggle to meaningfully influence the war beyond long-range strikes. The early but limited shift to provide close air support at some scale led to losses, with the RUS equivalent of strike and SEAD missions being largely ineffective. Early mistakes in the campaign have resulted in enduring costs. The eventual introduction of a more sophisticated air campaign was hindered by the squandering of large numbers of high-end systems against targets of dubious military value early in the war, and the subsequent reliance on less capable systems (such as the ageing and inaccurate AS-4 KITCHEN) to compensate for dwindling stockpiles of better weapons.

Key Considerations:

- Although NATO intelligence communities overestimated RUS capabilities before the war, underestimating them now could be dangerous too. NATO must continue to improve its equipment, training, and doctrine to deter and/or succeed in any potential future conflict with RUS.
- In an air campaign, windows of opportunity may be fleeting – there are rarely near-term second chances. The importance of speed (accuracy and timeliness) in everything, from developing situational awareness to informing decision-making, is clear. Evolving our air and space operational art/design, underpinned by agile AirC2 structures and the exploitation of emerging technology, is crucial to achieving this.

Quality 'vs' Quantity: is a Patriot Missile costing $ 1–2 million a cost-effective solution to counter a Shahed 136 (with an assessed cost comparable to a basics family car)? The cost of protection should never lose sight of the value of your adversary's target.

The Quality 'vs' Quantity Balance

'The only thing more expensive than a first-rate air force is a second-rate air force.'[3]

While RUS likely still maintains huge stockpiles of unguided munitions, the war has significantly depleted its arsenal of high-end munitions. This has meant a shift to using large numbers of cheap one-way attack (OWA) UAVs, notably the Iranian-supplied Shahed-136, to augment smaller numbers of highly effective air-launched and naval cruise missiles. The implication is that the cost of capable AD munitions could vastly exceed that of the attacking projectile. For example, the use of a PATRIOT missile costing $1–2 million to engage a Shahed-136 (with an assessed cost comparable to a basic family car) is financially disproportionate and unlikely to be sustainable, especially as OWA UAV technologies mature and become more widely proliferated. Of course, any cost calculation for AD must also include the (often huge) value of the protected asset, but it is clear nevertheless that future AD models will need to include cheaper solutions (such as AAA) in addition to expensive, high-end SBAD systems. Being in the right place on 'the cost curve' is vital.

UKR has demonstrated good judgement in terms of its munitions expenditure, focussing efforts on systems which give the highest return. NATO nations will need to be imaginative in their ways of employment to ensure effective mass is optimized. And munitions stockpiles matter too.

Key Considerations:

- Increasing the sophistication and coverage of our IAMD is essential; this should include a balanced array of AD options (including radar-guided AAA and cheap short range air defences (SHORAD) as well as advanced SBADs). This would, in turn, provide the best chance for employing an appropriate weapon system for each threat type; AAA, for example, is a better long-term choice for engaging a cheap OWA UAV than expensive, stockpile-limited SBAD.

Train how we plan to fight – testing and evolving integration with SHAPE, Theatre Components, and JFCs is crucial to achieving results greater than the sum of their parts.

- We must be willing to objectively evaluate the cost/benefit of 'exquisite' technology. Achieving the correct balance between 'exquisite', high-performance weapon systems versus the mass of cost-effective 'good enough' munitions needs continued objective analysis.
- Three decades of relative peace have encouraged 'lean processes'; however, national defence and security strategies that enable each nation to expand across all domains at pace are essential. We need to find the right balance between long-term procurement that affords the stability which encourages industrial investment and potential expansion, with short-term agility afforded by discretionary funding to enable opportunistic purchases. We must be willing to accept risk to perfection in favor of speed in a time of crisis.
- Compatibility must be prioritized by nations, for example, interoperability, standardization and some old skills such as Aircraft Cross Servicing (ACS). To achieve this, we must agree and set the standards for interoperability in order to exploit the principles of 'plug and play'. Procurement consortiums offer an opportunity to reduce costs whilst increasing interoperability and volume.

Train How We Plan to Fight

'The VKS's (RUS tactical air force) transformation of 2005–2022 focused upon getting good equipment, but lacked the requisite enterprise-level development and focus (e.g. on training/integration with land and maritime domains) needed to deliver genuine and robust high-end capabilities or military effectiveness.'[4]

Whilst RUS made skin-deep improvements to training processes in recent decades, during larger exercises there was no genuine enterprise-level focus and improvement across key lines of development in training and integration, central to which should have been joint warfare. Following the invasion, there was nothing

There is no sovereign territory in space and 'democratization' of the ultimate high ground presents both opportunity and jeopardy.

that resembled a coordinated air campaign until the strike campaign against UKR Critical National Infrastructure that started in October 2022. Even then, there was little evidence of the sustained focus and cross-domain planning that would indicate the existence of an orchestrated strategic plan. RUS's inability to package forces or exploit effects across domains has resulted in effects which are less than the sum of its parts.

Key Considerations:

- Test and evolve 'integration by design' with Supreme Headquarters Allied Powers Europe (SHAPE), Theatre Components, and Joint Force Commands (JFC) to inform the development of C2 in joint/multi-domain operations that exploit force packaging and flow and effects aggregation combining integrated (kinetic/non-kinetic) fires and effects.
- Development of practices that support the intent of mission-type orders and allow the de-centralized execution of complex missions with reduced or minimal connectivity must become habitual in order to enable agility whilst countering the temptation for micromanagement.

'Democratization' of Technology

'In the last century our imagination outstripped our technological capabilities in all domains. UKR has demonstrated the importance of innovation in bridging the gap to enable us to fully exploit the available technology which now risks outpacing our imagination'.[5]

The democratization of key technologies across the Air and Space Domains have made many traditionally state-controlled technologies available to all. Satellites can be put into space more cheaply and swiftly than ever thanks largely to the rise of commercial providers in the space industry, and so the increasingly contested Space Domain offers both challenge and

Mobile Patriot Battery – The 'UKR Air Force's ability to survive to operate has been largely down to its effective mobile IAMD and its passive defensive measures'.

opportunity. UKR's agility and innovative exploitation of commercially available and easily sourced technology has allowed it to achieve outcomes we would not have expected.

Key Considerations:

- Space is key to enabling our top priorities, including Counter-A2/AD (C-A2/AD) and IAMD. Defensive options as well as more offensive capabilities will be a priority in this increasingly contested domain.
- The opportunities from and threats to commercial providers in all domains needs to be fully analysed, understood, and then protected or taken advantage of accordingly.
- Agility and innovation are crucial to maintaining a competitive edge in an environment of unprecedented technological development and availability, noting that innovation does not equal or rest on 'exquisite' tech. The high volume/low tech 'good enough' model may be more appropriate, and there is a real premium on imagination.

'Offence' in the Information Space

***'Maintaining competitiveness in the information space is crucial; the decisions to declassify key information allowed NATO to offer alternative, credible narratives.'*[6]**

The decision to declassify NATO Intelligence and release it as open source provided an opportunity to offer credible, alternative narratives, enabling Allies to counter RUS's established disinformation machine. However, speed and agility are crucial. UKR's integrated information operations design has highlighted the importance of playing 'offence' as well as 'defence' in the information space in order to dominate the narrative. Yet it is equally important to understand the totality of the audience. To Western commentators, UKR's dominance of the information space appears overwhelming, but analysis of the information environment and audiences in the Global South (for example) may tell a different story.

Key Considerations:

- NATO must continue to take the initiative and look for opportunities to advance and succeed with its narrative. Generating 'passive' reassurance at the military level, focussing on strength, unity, credibility, and deterrence, must be matched by 'offence' at the political level, calling out aggressive or malign behaviours.
- Consideration should be given to persistent influence operations well beyond NATO nations, focussing on countries which are neutral or have economic ties to RUS, by demonstrating the long-term economic and political benefits of aligning with the West.

We Must Re-prioritize Resilience

'The UKR Air Force's ability to survive and operate has been largely down to its effective, mobile IAMD and its passive defensive measures.'[7]

The resilience of the UKR Air Force has been underpinned by effective, mobile IAMD and passive air defences. UKR has practiced de facto Agile Combat Employment (ACE) for survival throughout the conflict and continued combat employment, to maintain a contested Air domain.

Key Considerations:

- Air denial is an effective strategy for the defender and we must establish our own credible A2/AD before any conflict to provide protection while we build forces to counter-attack and liberate any incursion into NATO. Resilience of such defences remains crucial.
- ACE is a key facet of resilience. Short to medium-term lines of development within the wider operational design of ACE should include dispersal, deception, hardening, and agility. All promote survivability and pose targeting/understanding problems for our adversaries.
- Resilience principles must be applied beyond tactical assets and apply equally to our AirC2 structures and logistic sustainment, crucial to which is protection of our people and our CIS systems.
- A 'whole of society' approach to the resilience and survivability of other critical capabilities including nations' industrial capacity, government functionality, banking and data systems, production, and logistics must be re-examined. All intersect with the Military Instrument of Power.

RUS Remains a Threat to NATO

'RUS in UKR today is not the same RUS as 18 months ago and it will not be the same RUS that NATO would face in a future conflict.'[8]

The current conflict has reaffirmed historic RUS tolerance for the significant attrition associated with artillery-heavy warfare. Putin's government is willing to weather levels of friendly losses and inflict indiscriminate violence on their adversary which would not be politically acceptable in the West. RUS resilience to economic levers is also worthy of note, from cloning brands to its mobilization of the population and elements of its economy. Militarily, RUS is driving efficiencies, focussing its efforts on fewer air platforms than before in order to enhance production, availability and training. RUS is now the junior partner to China and any ceasefire would likely see an increase in overt support from China to Russia. It is in China's interest to see the United States 'bogged down' and distracted in Europe. At the moment, RUS may consider that it has lost its ability to credibly threaten NATO conventionally, but may regain the capability to do so again in the next 3–5 years. Could RUS, in a future attempt, seize an otherwise unremarkable piece of land on its borders in a NATO country to test the Alliance's commitment to collective defence? Whilst at present RUS lacks the capability to threaten NATO conventionally as a whole, the 'will' remains, and the information effects of a small incursion that questions NATO's fortitude could have huge geopolitical implications if not effectively countered.

Key Consideration:

- Our air forces are not used to sustaining high losses; nor are our publics. We must re-set the paradigm for risk tolerance and rebalance the understanding of risk and reward in a peer-peer or near-peer fight.

Conclusion

Failure to achieve air superiority has led to a stalemate on the ground in UKR. The prolific use of artillery, and the resulting mass destruction of civilian areas, (which would be unacceptable for the West) has forced both sides into fighting a prolonged land-focused attritional conflict. Had RUS been able to achieve air superiority at the start of the campaign, the conflict would likely have been over very quickly. UKR has displayed an adept handling of a layered IADS that has leveraged mobile systems employed with great agility.

The addition of Western air defence systems to the UKR IADS has further enabled donor equipment to flow freely into the country without being targeted from the air. The evolution of RUS A2/AD capabilities creates a dilemma for the Alliance, and an effective counter to these capabilities is key to enabling NATO's defensive contingency plans. In addition to investment and training in effective C-A2/AD capabilities, Alliance nations must accelerate additional investment in IAMD and address this as a priority, along with sophisticated MDC2.

The RUS invasion of UKR has precipitated numerous unintended second-order effects, from the demonstration of NATO's resolve, unity, and expansion, to a shift in doctrinal focus away from COIN and back to peer/near-peer warfare. Whilst lessons from the Cold War offer a start point to reinstating the principles and practices of countering a conventional RUS threat, the UKR Crisis provides an unparalleled opportunity to examine the impact of changes to the technological and geopolitical landscape. The pervasiveness of the information space as well as accessibility and democratization of new technologies are central to this. NATO's ability to evolve from joint to multi-domain 'integration by design operations' will be critical and will necessitate enterprise-level integrated training combined with the exploitation of emerging technology.

Finally, the conflict continues to evolve at pace. These assessments are already being updated and tested as the cycle of learning and adaptation in wartime continues for both Ukraine and Russia. ●

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2. Sqn Ldr (Rtd) Rob Smith, Senior Analyst, AIRCOM A2, speaking at the Allied Air Command Lessons from Ukraine: Implications for NATO Air & Space Power Conference on 8 June 2023.
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6. Ibid. 1.
7. Ibid. 2.
8. Ibid. 3.

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Navigating the Final Frontier: NATO's Strategy for Heavy Space Lift

A Diversified and Resilient Space Industry is a Strategic Imperative for NATO

By Major Arda Ayan, TÜ Air Force, JAPCC
By Major Brian Ladd, US Space Force, JAPCC

> *'One day, mankind will walk in the skies without a plane, go to the planets, and perhaps send us news from the moon.'*
>
> Mustafa Kemal Atatürk
> (Eskişehir Aircraft Regiment in 1936)

Introduction

Space launches drive the space race through their technological brilliance, scientific development, competitive advantage, and national prestige. Space Launches are the key enabler – and limiting factor – to the current commercial space enterprise. While of course a statement of technological prowess and national prestige, a robust domestic space launch capability should be understood first and foremost as a strategic imperative.

Rocket engines are essential to every space launch, making their availability a crucial element in sustaining any nation's ambitions in space. Unfortunately, most NATO countries are strategically vulnerable when it comes to the availability of rocket engines. It is therefore crucial to diversify supply chains, build domestic capabilities, and promote international cooperation to guarantee the resilience and autonomy of space programmes essential for both military and civilian applications.

This article will provide a brief history of the Russian RD-180 engine and the consequences of reliance on this engine, a description of NATO nations' current launch capabilities, an analysis of commercial, civilian, and governmental launch needs, and finally, recommendations for NATO nations such as opportunities to develop domestic and collective rocket engines.

Problem: Dependence on the RD-180

Russia first developed the RD-180 rocket engine in the 1990s for use in the first stage of the American Atlas V launch vehicle, which is currently operated by United Launch Alliance (ULA), a joint venture between Lockheed Martin and Boeing. Since then, NATO nations, including the United States, have depended on the RD-180 to launch military and intelligence satellites into space. The RD-180 was the first Russian-built engine launched from outside of Russia. With a notable thrust-to-weight ratio, the RD-180 can propel large payloads into space with considerable power. It has a dual nozzle and dual combustion chamber design that can be throttled for variable thrust levels during flight. The engine produces up to 860,000 lbs of thrust at sea level.[1] The US has received 122 RD-180 engines from Russia, 104 of which have been employed by the US military for several national defence missions. The RD-180 has been essential to the success of the Atlas V, one of the most dependable and economical launch vehicles currently on the market.

Regardless of the political tensions between the two nations, the Russian and American space industries worked together to develop the RD-180 engine. The decision to use Russian engines was not only technical, but it also had to do with US government policy following the fall of the Soviet Union to cooperate on broader non-proliferation initiatives by peacefully engaging with the Russian aerospace industrial base. Despite the Atlas V's perfect launch rate, Russia's invasion of Crimea in 2014 served as a

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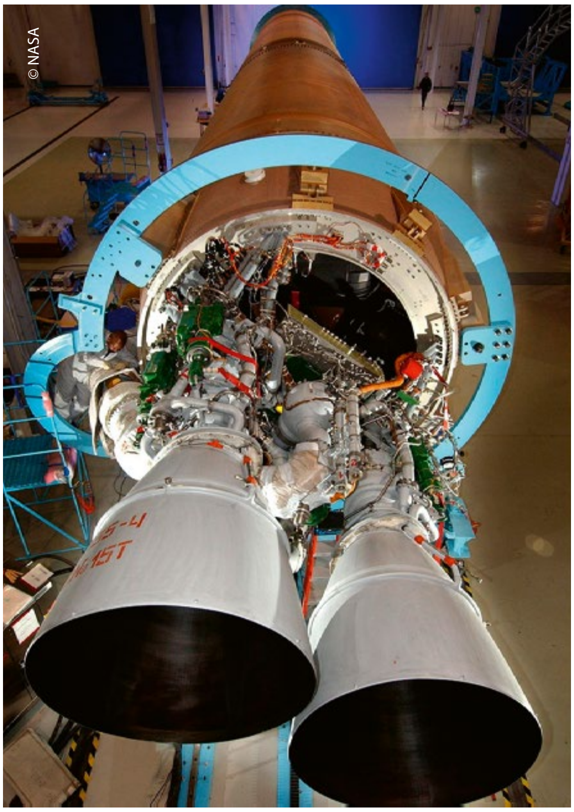


While presenting a short-term strategic challenge to the Alliance, losing the RD-180 creates an opportunity for a more resilient indigenous space industry independent from adversary nations' influence.

wake-up call for the US to find an alternative. Following ongoing tensions between Russia and Western nations, the US Congress expressed concern and directed the establishment of a domestic launch capability, whereas other space-faring NATO nations merely expressed concern about the reliance on Russian rocket engines but did not propose or direct divestment from Russian engine technology.[2]

In response to the US congressional mandate, Blue Origin began to design a new engine to replace the RD-180, the Blue Engine-4 (BE-4). BE-4 engines will power the first stage of ULA's new rocket, Vulcan, which was designed to replace the Atlas V. The BE-4 is projected to be a qualified reusable medium-to-heavy lift booster for all orbital planes; however, the BE-4 is currently undergoing full-scale engine development testing and recently experienced a catastrophic test failure raising concerns for its future-ready date.[3] ULA is aiming to launch 25 missions in 2025, of which half will be government missions and half for commercial customers.[4] SpaceX is also competing in the medium-to-heavy lift market, having designed and recently demonstrated their reusable Merlin engine. Reusability is fast becoming the desired future for the launch vehicle industry as it can significantly reduce costs in the long run. These programmes aimed to ensure the US would have greater control over its access to space and less reliance on vital components sourced from geopolitical adversaries.

Following its full-scale invasion of Ukraine in February 2022, Russia formally announced that it would no longer sell or support the RD-180 to any country that aids Ukraine. This decision validated the US concerns from 2014 and emphasized the need for the US space industry to establish lasting independent launch programmes. In contrast to the US approach, the absence of a comparable decision by other NATO spacefaring countries has proven to be a strategic vulnerability. Even with efforts to lessen reliance on them, Russian rocket engines have been crucial for NATO members for 30 years. The Alliance's reliance on these engines not only harms domestic supply chains for rocket engines, which has led to delays in space launches for NATO nations, it is also a strategic vulnerability to the Alliance's long term security interests in space.

Russia's decision on RD-180 was not the only example of how, since the start of the invasion of Ukraine, the decades-long space cooperation between Russia and the West has deteriorated significantly. Scheduled for liftoff on 5 March 2022, the Soyuz rocket loaded with 36 OneWeb satellites became the first space launch cancelled because of the Russian war against Ukraine.[5] Eutelsat OneWeb is a subsidiary of Eutelsat Group, formed through the combination of Eutelsat (France) and OneWeb (UK), to build a constellation of 648 broadband satellites. Russia's decision to stymie one of its space agency's most important commercial clients was the clearest example yet of how the conflict in Ukraine was spilling over into space. The move further isolated Russia's space agency from its Western space partners and severely restricted Russia's private space activities.

Until an alternative is found, Alliance members will have to limit the scope or frequency of their space missions and look to the US industry to fill the newly exposed gap. However, the US alone is insufficient to meet the launch needs of the entire Alliance, considering the average current and future launch rates. The impact of Russian engine elimination on NATO countries' access to space will be determined by how they respond to these challenges. NATO nations face a decision point: either maintain the status quo and endure a vulnerability or follow the US blueprint and create resilience for future space programmes. If the latter is chosen, there may be short-term impacts due to the long development cycle of creating a new launch programme, but it is an opportunity for NATO nations to invest in their own space technology and reduce their reliance on foreign engines in the long term.

Current Launch Capabilities within the NATO Nations

NATO does not own space assets directly. Nonetheless, it plays a significant role in coordinating and ensuring the security of space activities for its member states. Several NATO members maintain their own space programmes and are actively involved in launching satellites for a range of purposes, including military, governmental, and civilian applications. These space programmes are critical for national security, communication, scientific research, and more. Few NATO members have independent space launch programmes, but the Alliance's framework for collective security, information exchange, and cooperation binds them all together.

With considerable space-based capabilities, the US is the most active NATO member in terms of launch capability, as depicted in Table 1.1. Aside from US providers, the Ariane rocket family, operated by the European Space Agency (ESA), is used to launch both commercial and governmental satellites. The final Ariane 5 launch occurred on 6 July 2023 after 27 years of service. Ariane 6 initially planned to begin flying in 2021 to replace the Ariane 5. Nonetheless, the programme has experienced difficulties, and its first launch is now expected in June 2024.

Vega – the smallest member of Arianespace's rocket fleet – carrying a high-resolution imaging satellite into orbit for operation by the Turkish Ministry of Defence.

An analysis of Table 1.1 reveals alarming trends that deserve attention.

1. The US currently provides the only option within NATO to place a space asset into Geostationary Orbit (GEO).

2. The only proven launch-capable asset available from the rest of NATO is the Vega. The Vega is operational, but its limited boost capacity restricts the types of missions the engine can support.

3. The stockpile of RD-180 engines is dwindling (only 18 remain for Atlas 5 missions), limiting the number of launches that can reach GEO.

Two noteworthy advancements are the expansion of satellite communication systems and the employment

Rocket type	Engine type	Developer	Country	Orbit	Max Payload	Total Launches
Falcon-9	Merlin	SpaceX	USA	LEO	22,800 Kg	280
Delta 4 Medium*	RS-69	Boeing	USA	LEO	28,790 Kg	29
Minotaur I	LGM-118	USA	USA	LEO	580 Kg	12
Minotaur IV	LGM-118	Northrop Grumman	USA	LEO	1,735 Kg	7
RS1**	E2	ABL	USA	LEO	1,350 Kg	1
Vega	P80	Avio	ESA	LEO	1,500 Kg	23
Atlas 5***	RD-180	Energomash	USA	LEO/GEO	18,850/8,900 Kg	104
Falcon 9 Heavy	Merlin	SpaceX	USA	GEO	63,800 Kg	8
Delta 4 Heavy	3x RS-68A	Boeing	USA	GEO	14,220 Kg	15
Ariane 5*	Vulcain 2	Snecma	ESA	LEO/GEO	20,000/10,865 Kg	117
Ariane 6****	Vulcain 2.1	Snecma	ESA	LEO/GEO	21,650/11,500 Kg	0

Table 1.1 Current Launch Capabilities of NATO nations.

** Retired.*

*** Not fully operational yet.*

**** Uses previously purchased engines prior to the Russian response to sanctions.*

***** In development status (not operational).*

of remote-sensing satellites for both military and non-military purposes. According to the Index of Objects Launched into Outer Space maintained by the United Nations Office for Outer Space Affairs (UNOOSA), there are 12,121 individual satellites orbiting the Earth as of 15 November 2023.[6] Because of technological developments and rising demand for space-based services, nations have increased space launches in recent years as seen in Figure 1. Figure 1 shows a marketed launch rate increase due to the commercial expansion in the space domain.

Civilian vs. Government Breakdown

The introduction of the Starlink and OneWeb mega constellations has significantly impacted the market for government payload launches. Armed forces or international space agencies normally carry out government space programmes, but the growth of private space enterprises has increased competition, resulting in lowered prices. While government organizations continue to fund long-term space exploration efforts and national security-related missions, commercial companies are pushing to be global providers of space data, products, and services for the world's citizens. With the rapid expansion of commercial enterprises like SpaceX and OneWeb, the competition for engines that were once exclusively accessible to governments has intensified. This surge in demand for engines in the LEO sector has created a highly competitive environment.

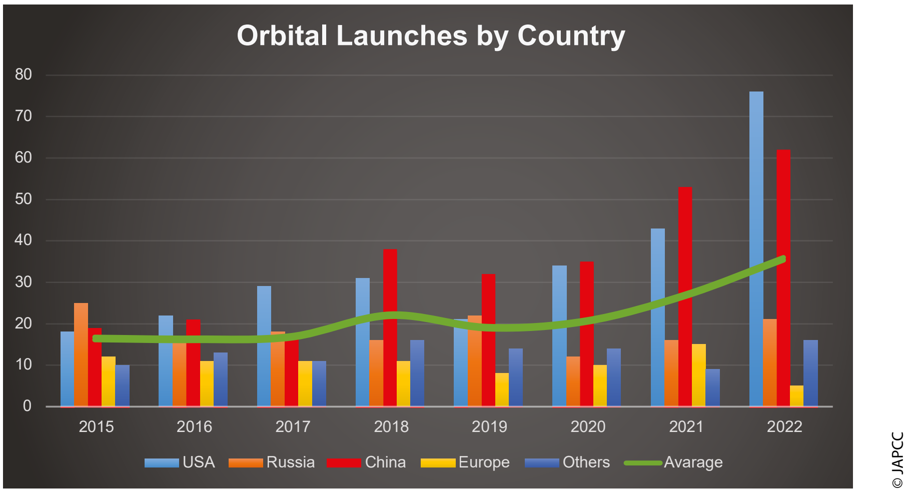
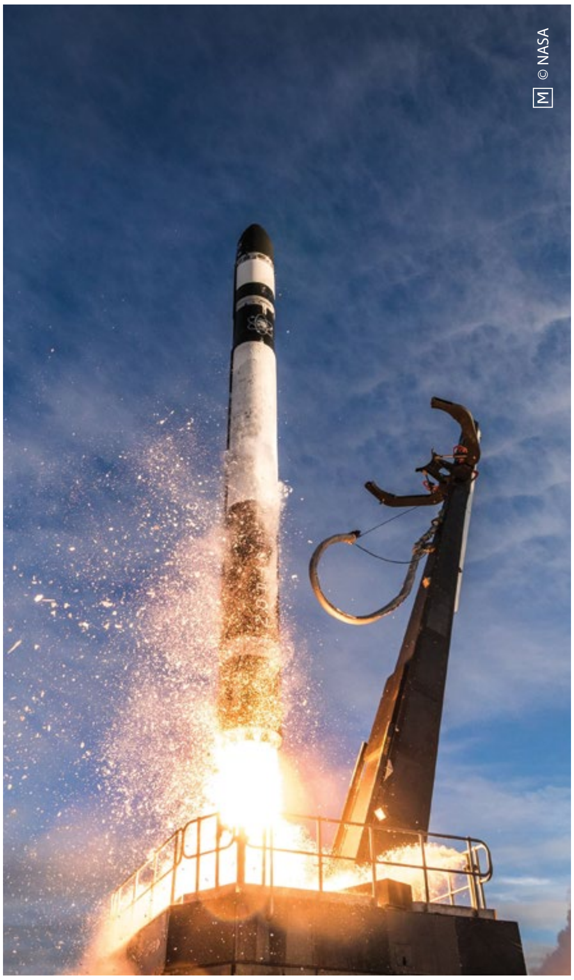


***Figure 1:** Orbital launches by country since 2015.*[9]

Expanding the world's space industry is one of the most notable reasons for the exponentially rising demand for space launches. Launch costs are forecasted to decrease, which will trigger more companies to access space, further exacerbating the availability of launch engines. Satellite manufacturers, space launch service providers, and technology innovators stand to gain as they scale up to meet the growing demand. Commercial launch service providers such as SpaceX, Rocket Lab, Blue Origin, and ULA are developing rocket engines to improve performance, dependability, and reusability. Companies like SpaceX and Rocket Lab have been able to cut costs. SpaceX has perfected its design by using reusable engines such as the Merlin and the new Raptor. Likewise, Rocket Lab is developing the heavy lift Neutron engine, designed for mega constellation deployment, deep space missions, and human spaceflight with a fully reusable first stage and fairing.[7]

The average rate of objects launched into space annually between 1957 and 2013 was around 118, which helps provide context for the average rate of 936 for the last ten years.[8] The latest advancements in small satellite technology bring an unprecedented new volume of spacecraft into orbit; the largest expansion are systems operating in Low Earth Orbit (LEO). In 2021, there were approximately 4,400 satellites in various orbital bins – including LEO, Medium Earth Orbit (MEO), and GEO. As depicted in Figure 2, the projected increase of satellites in orbit sheds light on the urgent need for expanded launch capabilities.



Reliable launch vehicles such as Rocket Lab's Electron rocket facilitate regular and adaptable entry into space.

SpaceX launched its first round of 60 Starlink satellites into LEO in May 2019 on one of SpaceX's Falcon 9 rockets. Today, the company has over 5,000 satellites in orbit, with aspirations to have a constellation of 42,000 within the next ten years. The impact of SpaceX (Starlink) is clear as seen in Figure 2, but we must consider it an outlier as SpaceX controls all the phases of production unlike any other company. NATO nations must instead focus on the projected 200 % growth only seven years.. As SpaceX prioritizes their own engines to deploy Starlink, the launch industry must find a way to pay the 200 % growth bill now to meet the need by 2030.

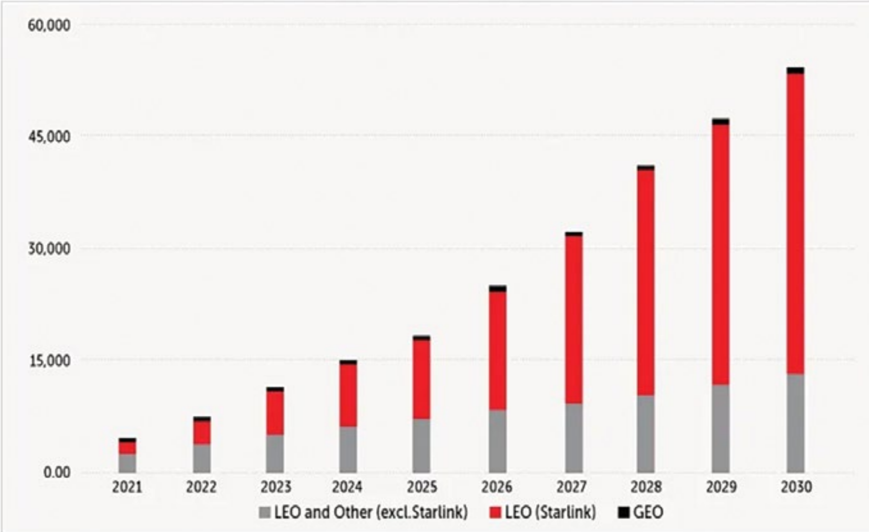


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***Figure 2:** Falling launch costs have contributed to a surge in customers, increasing competition for launch slots.*[10]

Recommendations: Domestic Launch Investments and Collective Opportunities

Considering the arguments presented above, the suggested recommendations to meet the NATO's Strategy for Heavy Space Lift are listed below.

- Rocket engine R&D should be a collective effort to encourage cost reductions and to expand launch technology.
- NATO nations should prioritize their launch investments in rocket engine production.
- Establish a set of guideline standards for engine design to improve opportunities for interoperability. This establishes a uniformity that can lead to efficiencies in other elements of the launch process, such as launch pads and fuelling systems.
- Nations must focus on payloads designed for LEO until launch programmes that deploy to GEO are widely available.
- All future space launch programmes should consider reusability as the most reasonable path for cost-effectiveness and debris mitigation.
- NATO nations must not fall back on utilizing Russian engines once the war of aggression has concluded and must avoid future dependencies with nations that hold interests counter to NATO's.

Conclusion

Russia's invasion of Ukraine and subsequent removal of RD-180 engines from the international market has proven to be an epiphany for many NATO nations with aspirations to access space. In the short term, the US decision to diversify launch capabilities has enabled the NATO Alliance to weather the storm; however, due to the expected increase in launch need, the US will no longer be able to be the sole provider of the Alliance's access to space. Rocket engines are essential to access space, and the availability of rocket engines is a crucial element in sustaining any nation's level of ambition in the space domain. Adopting these recommendations will enable the Alliance to be resilient to future disruptions to the launch sector while transforming the Alliance as a global leader in the space domain. Failure to adapt to the tidal wave of launch needs will put the Alliance's leadership position in the space domain at risk, and NATO nations may cede the initiative in space to adversaries. ●

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How Large Language Models are Transforming Modern Warfare

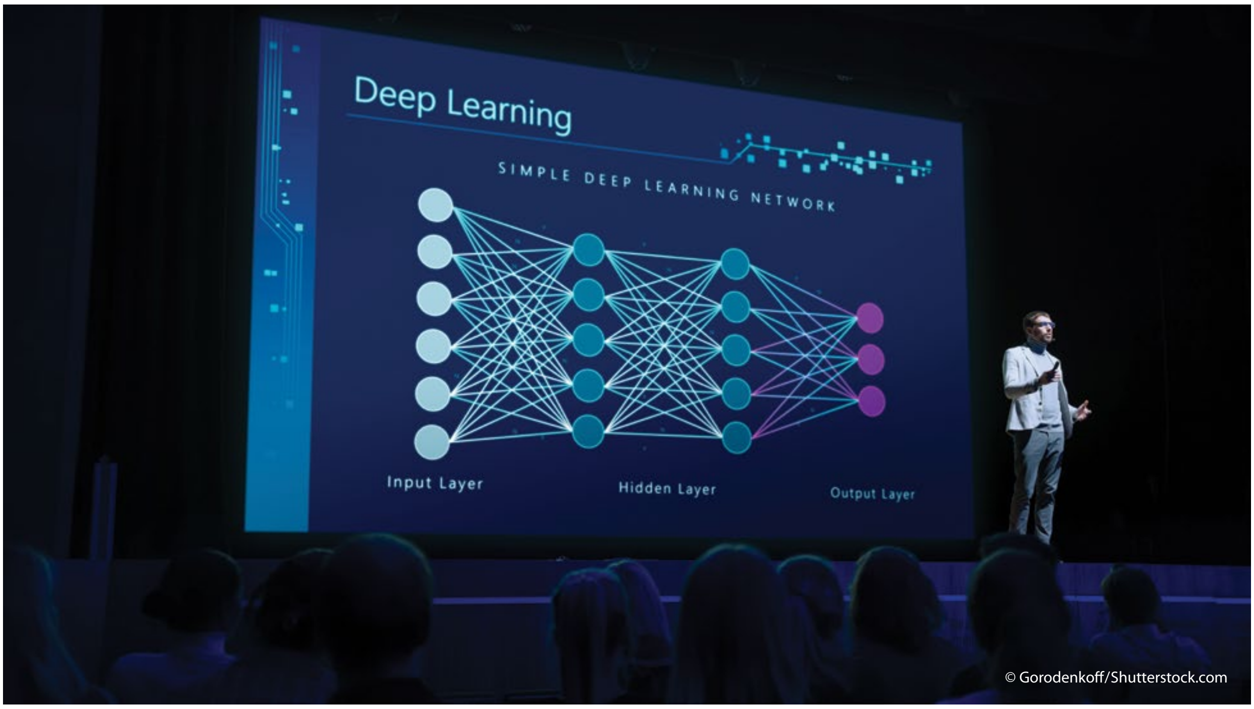
Is ChatGPT Applicable in the Military Domain?

By Lieutenant Colonel Antonios Chochtoulas, GR Air Force, JAPCC

Introduction

In October 2022, OpenAI released its novel Artificial Intelligence (AI)–driven chatbot, the famous ChatGPT (Chat Generative Pre-trained Transformer).[1,2] From that moment, the world entered a new era, where AI is at the core of the digital transformation. In the blink of an eye, the entire planet gained the privilege of using a sophisticated AI tool that can succeed in law exams, write computer code, school papers, fiction, and cooking recipes, and understand what a picture contains and draw logical conclusions, often in a human-like manner. Yet, few deeply understand what a GPT is and how it works.[3]

Although AI and Machine Learning (ML) are already successfully used for pattern recognition, filtering, and other purposes, their narrow scope focuses on a specific task. In contrast, ChatGPT and similar text-generation systems have a broader scope that is



LLMs leverage Deep Learning, a subset of Machine Learning. Deep Learning involves a neural network with three or more layers, designed to mimic the complex functions of the human brain and enable it to analyze and learn from vast datasets.

inherently closer to the human domain. Their remarkable capabilities in understanding, generating, and processing human language leads to diverse private sector applications, including content creation, language translation, medical diagnosis, customer service, and scientific research.

Many individuals categorize this technology as disruptive, analyzing its impact on the global landscape. Indeed, AI solutions like ChatGPT provide individuals and businesses with robust language-processing tools, granting easier access to vast amounts of information and allowing them to process routine tasks more efficiently, thus altering how we interact with computers and transforming how we work.

This article aims to provide an overview of the technologies powering ChatGPT within the broader AI landscape. It will also present the numerous challenges associated with their deployment, propose potential military applications, and finally put forth general guidelines for possible safe and successful uses in the military that are worthy of consideration.

Generative AI and Large Language Models

ChatGPT and similar text-generation systems are powered by Large Language Models (LLMs), a form of Generative AI. The latter encompasses a wider category of AI systems, designed to autonomously generate new content, or outputs by leveraging learned patterns and data. Content-wise, this technology spans a spectrum of content types, including text, speech, video, and images, without the need for explicit instructions for each output. Unlike traditional AI systems bound by pre-programmed rules or specific inputs, Generative AI possesses the capacity to independently create new, derivative outputs that are contextually relevant.

Specifically, LLMs are statistical models, leveraging Deep Learning (DL) principles and sophisticated internal mechanisms to create word sequences in any given language, thereby generating coherent and contextually relevant text.[4,5] Their primary function involves analysing patterns and relationships within text corpora to gain the knowledge and ability to assess the statistical likelihood of specific words or

Military air operations could greatly benefit by using LLM technology to enhance several activities, including those supporting planning and decision-making processes.

word sequences based on the preceding context, generating content that exhibits a natural or human-like quality.[6]

LLMs' operation comprises two primary phases: ***training*** and ***generation***. Training entails two stages. First, the model learns statistical patterns from extensive text datasets and adjusts its multi-billions of internal parameters to develop a general word prediction capability. Secondly, a fine-tuning process, utilizing human feedback to model outputs, optimizes word prediction accuracy within given contexts, thus shaping the models' final form. Once trained, the system applies its acquired knowledge to generate new output in response to prompts, continually refining its output based on previously generated content and provided context until the desired result or completion conditions are reached.

In 2020, OpenAI unveiled GPT-3, the first model that showcased remarkable performance across diverse Natural Language Processing (NLP) tasks.[7] At that time, GPT-3 excelled in text completion, translation, summarization, and question-answering, garnering considerable public attention. Its impressive self-learning capabilities allowed the model to execute tasks with minimal examples or training.[8] Its successor, GPT-3.5, ChatGPT's revolutionary model, is more powerful and offers even more extensive NLP capabilities. Introduced earlier this year, GPT-4, OpenAI's latest model, continues to push the boundaries of NLP, offering greater accuracy thanks to its broader general knowledge and advanced reasoning capabilities. In addition, this model offers both text and image input and output. [9,10]

Potential Applications of LLMs in the Military Domain

While the military and defence sectors have investigated various AI applications, including cybersecurity, maritime security, critical infrastructure protection, and others, there are no publicly known examples of LLM technology use. However, LLMs'

LLMs could potentially aid Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) processes by assisting the human operator in collecting, analyzing, and assessing data in real time.

exceptional capabilities in combining and analysing raw data from diverse sources, along with their NLP capabilities, make the military domain an area with immense potential.

Military air operations could greatly benefit by utilizing this technology to enhance several processes, including planning and decision-making. For example, one possible application of AI could involve assisting military commanders in making the right decision at the speed of relevance by supporting the staff's development, assessment, and recommendation of the available Courses of Action (COAs). LLMs could also aid Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) processes, by assisting the human operator in collecting, analysing, and assessing data in real-time, thus shortening the OODA loop and providing a decisive advantage on the battlefield.[11] Another area of potential application could be military exercises, where Generative AI tools could assist in creating more realistic scenarios and even augment understaffed Red Forces, for better and more efficient training.

Challenges Associated with LLM Technology

However, it is crucial to acknowledge that the full integration of LLMs may encounter challenges, such as ensuring quality training data, refining model capabilities, managing resource costs, and addressing ethical, legal, and bias concerns.

Addressing these challenges is decisive to ensure that adopting LLMs genuinely enhances the existing processes without compromising the integrity and safety of military operations, not to mention broader societal values and interests.

Ethical Challenges

Bias in Data

It's important to note that LLMs are trained using massive datasets, which include inherent and typically insidious biases, such as geographical, gender, social, ethical, moral, and religious ones.[12,13] If these biases are not addressed, LLM outputs may perpetuate or amplify existing biases, leading to false, unfair, or discriminatory outcomes. In military operations, bias in LLM-generated information or decision-support systems could have serious consequences, including the potential for discriminatory targeting, inappropriate mission prioritization, or inadequate resource allocation.

Addressing bias requires that careful attention should be paid to the training data used, and to develop and implement bias-mitigation strategies. Researchers are working on bias mitigation techniques such as dataset curation, model fine-tuning, and continuous evaluation of the outputs, to ensure the quality of the output.[14]

The Issue of Accountability

Furthermore, the use of LLMs or any other kind of AI technology raises concerns about accountability for decisions and actions, that have been influenced by or based on AI-generated information.[15,16,17] Ensuring accountability involves transparency, traceability, and the ability to attribute decisions to specific individuals or systems. However, researchers have argued that 'the inner workings of AI and ML systems are difficult to understand by human beings and are considered black-box methods where only inputs and outputs are visible to users.'[18]

This statement questions the trustworthiness of such systems, as the opacity of LLMs' internal workings makes it challenging to pinpoint responsibility in cases where errors, biases, or controversial outputs arise. On the other hand, we should also consider the level of effectiveness and transparency in human decision-making processes, as the imperfect nature of the human brain often leads to decisions that are wrong or ineffective, difficult to explain, or influenced by bias. The limited processing capacity of the human brain could amplify this phenomenon.

'Military commanders might need to respond fast to complex and high tempo situations in future warfare, especially when facing near-peer competitors. In that case, using LLMs to form semi-autonomous Human-on-the-Loop (HOTL) or even autonomous Human-out-of-the-Loop (HOOTL) systems, to maintain superiority on the battlefield, might be inevitable.'

Another aspect worth our consideration is that adversaries who prioritize operational advantages over moral and ethical considerations might adopt LLM systems despite their flaws and drawbacks. Other militaries, even inside the Alliance, could follow their example, by adopting and utilizing similarly imperfect AI solutions out of the fear of losing their advantage on the battlefield. In this possible future operational environment, the risk of compromising mission success, violating human values, and putting lives in danger may exceed our capacity to manage effectively.

Financial Challenges

Financial Cost

The economic burden of LLMs could be a significant challenge for some militaries, as the costs associated with training and running those systems, added to the essential investments required for capacity-building, can be very high.[19] Training large-scale LLMs requires a substantial financial investment, purchasing high-performance hardware, such as servers, storage, and networking equipment, and considerable energy consumption.[20] Additionally, acquiring and curating diverse datasets for optimal performance demands specialized skills and significant resources. Deploying LLMs in real-time applications further entails ongoing operational expenses, including maintenance and operating costs.[21]

'LLMs' ability to process, integrate, and analyse data from diverse sources, and to generate human-like responses to human inputs at the speed of relevance could support strategic agility, improved situational awareness, improved decision-making process, and efficient resource allocation.'

Further underlining the challenges that this technology poses, we should consider that nations constrained by defence budgets and limited resources may find it infeasible to adopt and integrate this technology, potentially leading to a technological and capability gap inside the Alliance. A solution worth investigating could be establishing mechanisms to fund and develop shared AI systems for use between North Atlantic Treaty Organization (NATO) Allies, similar to NATO's Airborne Warning & Control System (AWACS) programme.

Skilled Workforce Cost

Developing a skilled workforce is another critical aspect of capacity-building, especially considering the shortage of AI experts worldwide. Militaries should invest in training and education programmes to equip their personnel with expertise in data science, ML, NLP, and other related disciplines. Additional investment in research and development is essential to fine-tune LLMs for military applications. Research efforts should aim to improve model performance, address limitations and biases, and tailor LLMs to meet military-specific use situations.

Technical Challenges

Coherent Strategy

The successful integration of AI solutions within organizations generally hinges upon formulating a coherent strategy and robust business case.[22] For LLMs, that means militaries shouldn't make a rushed decision to adopt this technology without analysing and evaluating their processes in depth, and also considering the broader operational landscape. Otherwise, the absence of either of these two foundational elements – a coherent strategy and robust business case – will probably endanger the project's success.

Legacy Systems and Data Quality

Integrating LLM systems with existing legacy systems poses another significant challenge, as it is most likely that extensive system modifications will be required, consequently raising the risk of not meeting the desired outcome. Another critical concern pertains to the quality of data employed for training AI systems, as low-quality data can heavily impact the function of algorithms, undermining the potential for accurate outcomes and yielding consequential ramifications.

Hallucinations

There is also the issue of hallucinations when examining LLMs. This term refers to a phenomenon wherein LLMs generate plausible-sounding outputs completely fabricated, or detached from the input or context.[23,24] Hallucinations happen due to various reasons. Some include vast amounts of uncured training data, lack of contextual understanding, rare and unusual inputs, and language modelling techniques that LLMs are trained on. As a result, LLMs can occasionally produce outputs that go beyond their intended purpose or exhibit overconfidence in their responses.

Unfortunately, hallucinations and overconfident responses may not be obvious, and could pose risks in military operations, leading to misinformation, flawed decision-making, and potential mission failures. Researchers are investigating several mitigation strategies

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Given the high stakes of military operations and the legal and moral necessity for oversight, collaborative, 'teaming' arrangements are typically most appropriate; they are also more effective.

to address this issue, including human oversight and specifically designed algorithms to check the outputs continuously. In any case, we should develop and establish effective mechanisms to detect and mitigate hallucinations to ensure the reliability and validity of LLM-generated information.

NATO's Strategy on Cyber, AI and EDTs

The Alliance shows great interest in Emerging and Disruptive Technologies (EDTs) like AI, quantum technology, and autonomous systems. NATO has identified AI as one of the nine priority technology areas to focus its innovation activities. NATO's 2022 Strategic Concept states that '*Innovative technologies are providing new opportunities for NATO militaries, helping them become more effective, resilient, cost-efficient, and sustainable.*' [25,26] The same document affirms that EDTs bring both opportunities and risks, and that they are altering the character of conflict, acquiring greater strategic importance, and becoming key arenas of global competition.

Additionally, in an effort to promote the ethical use of AI systems, the United States Department of Defense (DoD) released principles for the ethical and lawful adoption of AI systems in the military in 2020, stating, among others, that '*The United States, together with our allies and partners, must accelerate the adoption of AI and lead in its national security applications to maintain our strategic position, prevail on future battlefields,*

and safeguard the rules-based international order'.[27] NATO has also released similar principles, including lawfulness, accountability, explainability (sic), traceability, reliability, and bias mitigation, to address the challenges posed by AI in the military.[28]

Conclusion

The potential use of LLMs to assist humans and enhance military processes holds great promise and could offer significant advantages for achieving operational and even strategic objectives. LLMs' ability to process, integrate, and analyse data from diverse sources, and to generate human-like responses to human inputs at the speed of relevance could support strategic agility, improved situational awareness, improved decision-making process, and efficient resource allocation. Additionally, this technology could assist in identifying blind spots, providing valuable insights, and aiding in complex cognitive tasks.

However, bias in the training data, accountability for model outputs, and potential hallucinations all highlight the importance of maintaining human oversight and responsibility in decision-making processes. Acknowledging these challenges and implementing proper mitigation mechanisms is essential for properly incorporating LLMs into military decision processes. In addition, the significant investment required to train and run these systems must be balanced with the potential benefits they bring to military operations. We should also keep in mind that some militaries will struggle to cope with the associated financial costs. In contrast, others will harness the benefits of this technology, potentially creating a technological gap inside the Alliance.

Due to the challenges and drawbacks currently associated with this technology, it is crucial to consider LLMs as supportive tools, rather than autonomous decision-makers. The human factor should remain central, with LLMs providing data-driven insights and recommendations to complement human expertise, forming Human-in-the-Loop (HITL) systems.[29] Adopting such a supportive approach can capitalize on the strengths of LLMs, while maintaining human agency, accountability, and responsibility in military operations.

Nevertheless, military commanders might need to respond fast to complex and high-tempo situations in future warfare, especially when facing near-peer competitors. In that case, using LLMs to form semi-autonomous Human-on-the-Loop (HOTL) or even autonomous Human-out-of-the-Loop (HOOTL) systems might be inevitable to maintain superiority on the battlefield.[30, 31]

While scientists and researchers are working to achieve Artificial General Intelligence (AGI), and LLMs are continuously becoming easier to implement and more efficient, their disruptive and transformative effect on society will become enormous.[32, 33] This technology's potential risk for individuals and societies is also considerable, underscoring the necessity for governments and organizations to prioritize AI regulation. Emphasizing this focus is essential to safeguard the technology, mitigate potential risks, and maximize the expected benefits. ●

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Lieutenant Colonel Antonios Chochtoulas graduated from the Hellenic Air Force (HAF) Academy in 1999 with a degree in logistics. He also holds a Master's degree in Computer Science and has cultivated over two decades of diverse experience in IT and Security. He began his career as a programmer and then progressed to roles like Systems and Database Administrator, developing expertise in Information Systems Security, Windows, Linux and Unix Systems Administration, and Database Security. As the former Head of the IT Department at HAF Air Supply Command and HAF Supply Depot, he managed critical security aspects within large organizations. Currently, he is assigned at JAPCC, in the C4ISRS Branch, and he contributes to multinational projects focusing on cyberspace.

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Strategic Horizons – Advancements in Air and Space for Deterrence and Defence

A Review of the JAPCC Conference 2023

By Colonel Markus Müller, GE Air Force, JAPCC
By Lieutenant Colonel Florin Sandu, RO Air Force, JAPCC

Introduction

Between 10 and 12 October 2023, the Joint Air Power Competence Centre (JAPCC) conducted its most prestigious annual event, the Air and Space Power Conference, to enhance deterrence and defence as one of NATO's core tasks. Experts from science, politics, industry, and the military discussed avenues for further developing Air and Space Power and better aligning it with current and future scenarios. Tremendously supported by 11 industry sponsors and more than 300 attendees with various backgrounds, benefitted from distinguished keynote speakers such as Admiral Rob Bauer, Chairman of the

Panel 3 discussed the future of air and space capabilities during the second day of the conference.

NATO Military Committee, General Christopher G. Cavoli Supreme Allied Commander Europe (SACEUR), General James B. Hecker, Commander US Air Forces in Europe and Africa, Commander Allied Air Command and General James H. Dickinson, Commander US Space Command. The three-day event provided a platform to discuss perspectives on enhancing, sustaining, and using Joint Air and Space Power as one of the most effective and efficient means to deter the global competitors which pose direct and indirect threats to the security, peace, and stability of not only the Euro-Atlantic region but also the world at large, as we are witnessing today.

Several themes that could have a positive impact on the readiness, availability, and credibility of Air and Space Power permeated through discussions and must be considered noteworthy. This article will briefly summarize these discussions without attribution under the conference's Chatham House rules. The ongoing war between Russia and Ukraine underscores the need for an immediate focus on today's and tomorrow's security challenges, emphasizing the crucial requirement for a collective effort throughout the alliance. It is imperative that we act together now to improve both the capability and capacity of our forces upon which our collective defence depends!

Through a comprehensive analysis of the conflict in Ukraine, valuable lessons have emerged that can serve as a foundation for developing innovative strategies in the military, societal, and economic domains. One crucial insight gained from studying this war is the significant role played by Air Power, or, more correctly, the distinct absence of decisive airpower by either belligerent. Despite Russia's haphazard pursuit of air superiority, they were unable to attain it, thanks to fatal flaws in their operational approach and the relentless efforts of the Ukrainians who displayed remarkable resilience and agility in their defence. This observation holds immense significance for our community of interest.

Now, the question arises: How can NATO, its member nations, the civilian sector, and industry collectively enhance the level of force readiness? This query demands careful consideration and collaboration; During the panel discussions, it became evident that eight specific areas hold significant potential for strengthening NATO's capabilities in deterrence and defence.

Strategic Vision and Planning

One critical issue that frequently arose in the debates was the pressing need for a change in thinking at the political level. It is crucial to fully comprehend the geo-strategic threat to our democratic values to allocate the necessary funds for the military for a credible defence, even if this decision may not be popular. Security should be carefully planned, and changes in priorities must be made as time is of the essence. Therefore, it is imperative to convince the public of the fundamental need to invest in defence by highlighting the real consequences that war can bring to all nations. Moreover, long-term strategic planning that aligns political objectives and military capabilities to meet plausible future warfare scenarios is essential.

Additionally, a profound shift in comprehending the strategic landscape is of utmost importance within the military sphere, as it serves as the key to achieving effective deterrence, as the perfect balance between capability and willingness. However, it is essential to recognize that aforementioned concepts alone may not always be sufficient, particularly when we closely examine recent conflicts (in Ukraine and Israel) that have been characterized by unexpected situations such as strategic surprise. As a result, it becomes imperative not only to transform the perspective of leadership but also to empower them to embrace uncertainty and think creatively, while making best use of recent advancements in technology. Additionally, it is crucial to foster a sense of purpose and understanding among fighters at all echelons of command and employment.

Technological Superiority

Advancements in aircraft, missiles, sensors, satellites, cybersecurity, artificial intelligence, and other innovative technologies are cost intensive, but essential. However, we live in a society with diverse needs and limited budgets and must therefore strike the right balance between quality and quantity in our endeavours. In this regard, it is crucial for each country to conduct a thorough analysis to determine whether their defence needs can be met with available funds. It is crucial to acknowledge that deterrence is significantly more desirable than embarking on a costly war. Hence, it becomes imperative for nations to explore avenues for enhancing their military capabilities, either by procuring state-of-the-art resources or upgrading their existing arsenal, all while prioritizing interoperability.

Ukraine is a prime example of the clash between quality and quantity. On one side, we witness modern Western equipment and technology, representing the epitome of quality, though often in insufficient quantity. Conversely, we see low morale and ill-equipped units attempting to overwhelm the battlefield through sheer numbers. The perpetual battle between quality and quantity imparts a significant lesson: there will never be an abundance of either. Hence, it becomes imperative to invest in innovative and efficient technologies while also attracting new personnel. However, it is important to note that solely focusing on quality or quantity without the other would render it inconsequential in the long run.

Therefore, NATO must speed up the processes associated with research, development, and procurement of new state-of-the-art technologies, concomitantly using its technological advancements to improve conventional military capabilities. Here, too, there is reasoned debate over what premium should be paid for marginal advances in performance.

Space Domain Awareness

A thorough understanding of the space domain, including enhanced situational awareness, surveillance, and protection of space assets, is increasingly important.

AIR DEFENDER 23 exercise significantly promoted interoperability, cohesion, and solidarity.

Addressing the multitude of air and space threats is an integral part of the concept of collective defence, and it is essential to have a common platform for sharing information and knowledge; military decision-makers increasingly rely on space-based assets to gain and communicate critical situational awareness. Accordingly, NATO is taking significant steps to establish space as a facilitator of air power and a catalyst for achieving strategic outcomes.

This vision entails the need for national or multinational programmes to collaborate effectively, ensuring resilience and redundancy in satellite constellations. Additionally, the private sector must play a crucial role in establishing robust space situational awareness. The military should leverage and integrate commercial assets, even though this association may expose commercial partners to non-physical, electromagnetic, or cyber threats, implicating updates in deterrence policy in space. Striking a balance between commercial and military satellites will require a layered approach, including formulating integration and protection policies that assure our Allies and partners.

Improve Interoperability

Increasing capability can be a challenging process, especially when it comes to acquiring expensive new capabilities like 5th generation aircraft. Costs may diminish the appetite for purchasing such assets. Therefore, it is crucial to consider interoperability as a potential solution for integrating old and new equipment to enhance every nation's capability pool.

Within NATO, large-scale multinational exercises have proven to be a unique opportunity to showcase the potential offered by interoperability between different nations, services, and platforms. These exercises preserve NATO's integrity, its population, and its territory. AIR DEFENDER 23, the largest deployment exercise of air forces in NATO's history, emerged as a significant promoter of interoperability, cohesion, and solidarity. It has laid the foundation for the future pattern of NATO exercises in the air domain, demonstrating our ability to support and employ the readiness of Joint Air Power in the long term. Multinational exercises continue to be crucial for fostering an interoperable force. Moreover, they serve as an integral component of deterrence, effectively sending a clear signal: we stand united and are prepared to respond promptly whenever necessary.

Training and Education

The operational readiness of armed forces, and thus the ability to deter, is based on the availability of materiel, and the necessary training and education of personnel. Education plays a pivotal role in this development, as tailored training scenarios enable the military to attain a higher individual and organizational performance necessary for integrating innovative technologies in warfare.

Hence, investments in defence education and training play a crucial role in enhancing the readiness and availability of military forces. Achieving practical cooperation within a multinational environment requires harmonizing educational processes across different countries. NATO military academies offer a wide range of courses for international students, bringing immense benefits in terms of knowledge sharing and best practices and fostering a collective understanding of warfare strategies. One outstanding example supporting these ideas is the Tactical Leadership Programme (TLP), which aims to elevate the effectiveness of Air Power by conducting exercises that range from mission planning and briefing to more complex tasks like flying large tactical composite air operations and developing conceptual and doctrinal initiatives.

Robust Command and Control Structure

A sophisticated and resilient C2-Structure enables efficient coordination, decision-making, and execution of operations across all domains. The fruitful implementation of modern capabilities relies heavily on a robust and reliable C2 system specifically tailored to enhance the deterrent effect: There will be no successful military operation without proper command and control to ensure the unity of effort. Though NATO member countries possess different versions of C2 systems, some are considered outdated legacy systems. There must be a collective will and commitment to update and prioritize interoperability and integration between these systems. Despite this diversity, Joint Air Power remains a credible, capable, and readily deployable force, capable of comprehensively defending NATO from 360-degrees when required.

Logistic Support

Effective Air Power requires seamless logistical support (ground and air) because a robust and efficient logistical infrastructure is the prerequisite to sustain operations by providing necessary supplies, maintenance, transportation, and support to deployed forces.

Debating the significance of logistics as a primary driver of success and a catalyst for enhancing capabilities is unnecessary. Throughout history, we have witnessed the decisive role logistics plays in determining the outcome of wars. The current conflict in Ukraine vividly highlights the stark contrast between the Ukrainian force that demonstrated exceptional skill in executing swift manoeuvres, deploying troops efficiently, integrating diverse equipment seamlessly, and sustaining their operations, while the aggressor struggles to equip, deploy, and support their military machinery. The logistics aspect of Russia's operational failures was no surprise to astute thinkers, underscoring the criticality of a modern, well-organized, and optimized logistical chain. However, within the NATO community, these observations have sparked a renewed discussion on how to further assist Ukraine while enhancing our ability to provide effective collective defence.

At the same time, the NATO Force Model (NFM) must significantly increase the total number of available and ready

Air Commodore Paul Herber, Assistant Director JAPCC, provides his vision for the JAPCC and NATO air and space power.

forces for planners. This monumental change will present challenges for nations, requiring them to invest in military infrastructure, recruit personnel, improve military mobility, procure new capabilities, and preposition equipment and associated stocks. Concepts like Agile Combat Employment and Resilient Basing are integral to the transformation necessary to accommodate the NFM structure. In order to progress, it is imperative to collaborate with industrial partners who can offer essential solutions to meet our expectations and further enhance interoperability.

Partnership and Collaboration

Strong partnerships between military forces, government agencies, industry partners, and international allies are necessary. Collaboration promotes trust, information sharing, and technological development and increases production capacities. Therefore, fostering improved communication between the military customers and the industry providers is crucial.

Collaboration and understanding between these two entities will ensure the military's needs are effectively met. By working together, we can navigate the challenges of the future and stay ahead of the ever-evolving technological landscape. To achieve this, it is imperative for the political level to allocate the necessary resources. Given the current geopolitical landscape and the limited time available to enhance existing capabilities, it is of utmost importance to shift towards collaboration and partnership.

Conclusion

In summarizing the earlier discussed topics, we confidently assert and support fundamental truths regarding crucial aspects necessary for advancing Joint

Air Power as a top-tier deterrent in our ever-changing geopolitical landscape. These aspects include a shift in mindset across societal, political, and military domains, the seamless integration of innovative technologies into warfare, and enhanced collaboration within and between the industrial, political, and military sectors.

Referring to the quote from Billy Mitchell at the beginning, who emphasized the need to look into the future for further development of Airpower, it is crucial to conclude that this approach can only be successful today if we work together with partners in a strong alliance like NATO.

For a comprehensive package on the Conference (Read Ahead, Proceedings and a Journal article), please visit our website https://www.japcc.org. We eagerly anticipate your presence in Essen, Germany between 8–10 October 2024 for the Joint Air & Space Power Conference, themed 'Challenges and Opportunities for Air and Space Power in an Evolving Security Environment'.

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Lieutenant Colonel Florin Sandu graduated from the Romanian Air Force Academy in 2001, earning a bachelor's degree in organizational management. He has held various positions throughout his career, including being a Tactical and Air Traffic Controller at the 71st Air Base Operation Centre in Câmpia Turzii, an Intercept Controller, and a Weapons Allocator for the Command and Reporting Centre. In Bucharest in 2017, he obtained his military college master's degree, graduating from the Romanian National Defence University. His further responsibilities included serving as the Head of Operations and Training Branch (A3), leading the Air Operations Coordination Centre within MNC-SE in Sibiu, and acting as the Chief of Staff for the 71st AFB, also on various operational deployments. Since August 2023, Lieutenant Colonel Sandu has served as a staff officer for Plans, Concepts, Development & Vision within the ACE Branch at JAPCC Kalkar, Germany. In this capacity, he contributes his expertise to strategic planning and developing innovative concepts for the organization.

Colonel Markus Müller

GE Air Force, JAPCC

Colonel Markus Müller started his military career in 1993 and was trained as Surface-Based Air Defence (SBAD) officer. He graduated from the University of the German Armed Forces in Munich and from the Air University, Maxwell AFB, attending the Air Command and Staff College. Colonel Müller has served in various staff assignments on tactical, operational and strategic level and in leadership positions from SBAD unit command up to SBAD battalion command (SAM Group 61). During his last assignment Colonel Müller worked at the Ministry of Defence in the Directorate General for Forces Policy in Berlin. His experience includes the NATO Operation 'Enduring Freedom' in Afghanistan being the Executive Officer of an Operational Mentor and Liaison Team (OMLT) and Operation 'Active Fence' in Türkiye, where the PATRIOT System was deployed for TBM defence. Currently, Colonel Müller is the Branch Head Assessment, Coordination and Engagement in the JAPCC. In this function, he also serves as the Conference Director for the annual Joint Air & Space Power Conference.


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JAPCC Hosts its Annual Joint Air and Space Power Conference 2024

Challenges and Opportunities for Air and Space Power in an Evolving Security Environment

Distinguished delegates, stakeholders, and experts in the field of Joint Air and Space Power have the opportunity again to attend our annual conference, scheduled to be held from 8 to 10 October 2024 at the Congress Centre 'Messe Essen' in Essen, Germany. This event presents a unique opportunity to delve into the theme of 'Challenges and Opportunities for Air and Space Power in an Evolving Security Environment'. Attendees can anticipate a rich and engaging two-day agenda, comprising of insightful panels, provocative sessions, and ample opportunities for networking and collaboration.

Beginning with Panel 1 – A World Reshaped: Navigating the Ripple Effects of Shifting Power Dynamics, we will explore the complex changes in global power dynamics and how they impact NATO's strategic landscape. From emerging conflicts to evolving international relations and rapid technological advancements, this panel will set the stage for following panellists and speakers.

Panel 2 – Battlefield Evolution: The Role of Joint Air and Space Power in Contemporary Conflict will focus on the crucial role of Joint Air and Space Power in shaping modern conflicts. Through a detailed analysis of adaptability and innovation, panellists will discuss how connectivity and technological advancements have transformed warfare. By examining examples such as Ukraine's innovations and the impact of connectivity on military operations, this session aims to shed light on the challenges and opportunities to operations brought by changing technology.

Panel 3 – Contested Air Superiority: Adapting to the Drone and Missile Age, will examine the implications of advanced drone and missile technologies on current offensive and defensive operational practices. As drones, loitering munitions, and precision missiles challenge traditional concepts of air dominance, this panel will bring together a group of experts to analyse the strategic, operational, and tactical consequences of these developments. Valuable insights will be shared to help maintain freedom of action in an increasingly contested airspace.

In conclusion, Panel 4 – The Role of Industry: Bolstering Deterrence Through Enhanced Capabilities will highlight the crucial partnership between defence agencies and industry in maintaining technological superiority. This panel will explore how industry can support NATO's efforts to advance emerging technologies and adapt to the changing nature of warfare. From production capacity to technological innovation, this session will provide a thorough evaluation of options to preserve our technological advantage.

The Joint Air and Space Power Conference 2024 aims to facilitate active engagement and meaningful dialogue among participants. Attendees will have the opportunity to interact with senior military and civilian leaders from NATO and various nations. Through lively discussions, sharing insights, and shaping the future of international security, participants will play a key role in advancing collective knowledge. ●

Stay tuned on:
www.japcc.org/conference

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10th Annual Joint Air and Space Power Network Meeting

Joint Efforts to Make the Euro-Atlantic Area Safer

On 14 and 15 November 23, the JAPCC hosted the 10th annual Joint Air and Space Power Network (JASPN) Meeting in Kalkar, Germany. The meeting, chaired by the JAPCC Assistant Director, Air Commodore Paul Herber, was the largest to date, with 13 stakeholder agencies in attendance. This event has become a valuable platform for sharing information, engaging in collaborative discussions, and fostering synergy between multinational organizations within the Air and Space Community.

This year, we were honoured to welcome a variety of esteemed organizations, including Allied Command Transformation, NATO HQ International Staff, NATO Science and Technology Organization, NATO HQ Military International Staff, European Air Group, European Defence Agency, European Air Transport Command, Movement Coordination Centre Europe, Command and Control Centre of Excellence, Integrated Air and Missile Defence Centre of Excellence, Space Centre of Excellence, and the Competence Centre for Surface-Based Air and Missile Defence.

The two-day event centered on General Hecker's five priorities: Counter-Anti-Access/Aerial Denial, Integrated Air and Missile Defence, Intelligence and Information Sharing, Command and Control, and Agile Combat Employment. The meeting highlighted the importance of these priorities in addressing threats such as conflicts on European borders, challenges posed by China, Iran, terrorism, and cyber and hybrid attacks. Throughout the discussions, participants agreed Alliance capabilities must be interoperable and integrated across all domains to support multi-domain operations and deliver multi-domain effects. Key areas of focus included the importance of data storage, processing, and connectivity, the quality and quantity of personnel, new weapons systems and ammunition, space and ISR collection capabilities, and ensuring continuity of operations by strengthening the resilience of critical infrastructure and the ability to operate from dispersed locations. Undoubtedly, these efforts will position the Alliance to be prepared for a new era of air power and near-peer warfare.

In order to prepare for and address new challenges, collaboration with partner organizations is necessary. Events like the annual JASPN meeting provide important opportunities for the Air and Space Power community to collaborate and align our work in keeping with changing demands. A comprehensive summary of the event has been shared with participants, containing a collaboration matrix, contact information, presentations, and discussion records.

Our thanks to all attendees. The event is held every November, and interested parties from multinational organizations similar to those above are encouraged to reach us at contact@japcc.org if interested in attending.

We eagerly anticipate future collaborations with these esteemed organizations. ●

Drone Drills: Essential Emergency Strategies

The New JAPCC White Paper on Immediate Drone Response Measures

Do you know what to do when you spot a drone flying above or outside your office window? Are you aware of the potential threats and hazards that drones can pose? Do you know the appropriate actions to take when encountering one? Moreover, do you know how to protect yourself and take necessary steps to ensure the safety of those around you?

The widespread availability of drones has introduced a spectrum of security challenges. Drones can capture high-resolution images, detect objects, and even transport explosives or other hazardous materials. Privacy concerns arise as advanced drones can record activities, conversations, and even documents, potentially exposing sensitive information. Safety risks are heightened when explosives are involved, as small amounts can cause significant damage and injuries due to the lack of blast-resistant structures in most buildings and the difficulties in detecting hidden charges. Additionally, even minimal quantities of hazardous materials carried by drones can cause severe health effects. The evolving landscape of cyberattacks adds another layer of complexity, where drones equipped with network hacking tools can bypass physical security to compromise networks and sensitive data.

Education and training are vital to address these issues, enabling personnel to recognize threats, understand drone risks, and implement appropriate protocols. While established protocols exist for common emergencies, organizations often lack specific plans for drone incidents, which are becoming more prevalent due to increased drone usage. Responses to drone incidents require tailored plans covering threat assessment, protection measures, and implementing immediate procedures.

Such measures are essential because effective response to drone incidents might be delayed as drone defence technology is not yet widely available. Therefore, immediate actions upon detection are crucial to minimizing harm, damage, and potential casualties. As with first aid and fire alarm procedures, regular drills are essential to ensure readiness and proficiency.

We highly recommend reading this newly published JAPCC document that delves into the immediate actions individuals should take in the first few minutes of a drone incident before the arrival of the guard force, police, or other first responders. It's crucial to note that this paper does not focus on technically advanced countermeasures provided by professional drone defence systems. Instead, its emphasis lies in guiding individuals on how to respond to a drone incident safely and effectively, in the same way we are accustomed to administer first aid before the arrival of an ambulance or evacuating the area before the bomb squad arrives.

Please visit ***www.japcc.org/drone-drills*** to download the paper, its customizable annexes, and additional educational references and materials.

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Ready to Support You…

How Nations and Organizations Can Request Support from the JAPCC

In light of the tense security situation worldwide, the Alliance and its member nations are facing the need to significantly enhance their operational readiness for effective deterrence and defence. As a result, support requests to the JAPCC are on the rise, necessitating prioritization due to limited resources and manpower.

The focus of our activities is guided by the Programme of Work (PoW), which encompasses over 130 active items. The PoW is shaped by the Steering Committee, which ratified JAPCC's 'focus areas' to align with the core concept of NATO accredited Centres of Excellence (CoEs): to supporting the Alliance's transformation across four functional pillars. The JAPCC leverages its academic freedom to serve as a key catalyst for NATO Airpower, fostering innovative thinking and actively contributing to NATO's transformation in collaboration with Headquarters Supreme Allied Commander Transformation.

Managing JAPCC's PoW is a dynamic process that adapts to formal Requests for Support (RfS) received through two main channels: the TRANSNET RfS Tool for NATO bodies and the RfS Form on the JAPCC website for Sponsoring Nations and NATO partners. To date, JAPCC has responded to approximately forty requests annually, in addition to providing standard support to NATO processes like NATO's Defence Planning Process initiated by Sponsoring Nations, with a high rate of positive responses.

The JAPCC leadership must carefully consider each request on a case-by-case basis to determine which ones can be processed and which ones must be declined based on the Centre's capacity. This highlights the importance of having a fully staffed Centre of Excellence, as not only are RfSs a priority, but also tasks such as concept and doctrine development, lessons learned, and support to large-scale NATO exercises depends on this capacity.

To manage the increasing number of requests, JAPCC is currently improving the RfS management process by streamlining it and prioritizing and categorizing tasks. This will result in an advanced interactive form on the JAPCC website which will benefit both the organization and applicants.

While it is disappointing when we must decline an RfS, we take heart knowing that our services are in high demand, and that we are selecting the activities that provide the greatest return to NATO and our Sponsoring Nations.

We take this opportunity to thank all our Sponsoring Nations for making our important work possible, and to encourage any prospective members to contact the JAPCC to explore the possibilities and benefits of membership. ●

NATO School and JAPCC Partner with European Air Group, Signing Memorandum of Agreement

The Memorandum of Agreement was signed by Air Commodore Paul Herber of the NE Air Force, Assistant Director of the Joint Air Power Competence Centre, in Kalkar, Germany (left). Subsequently, the agreement was also signed at the NATO School Oberammergau (NSO), Germany, by General de Brigade Aérienne Xavier Foissey of the FR Air Force, Deputy Director of the European Air Group (middle), and Colonel Jurjen Haan of the NE Army, Dean of Academics at NSO (right), on behalf of Colonel Jay Smith of the US Army, Commandant of NSO.

In January 2024, the NATO School Oberammergau (NSO), European Air Group (EAG), and Joint Air Power Competence Centre (JAPCC) signed a Memorandum of Agreement focusing on Education and Individual Training (E&IT) to strengthen their collaboration in the area of Force Protection (FP). The agreement specifically targets NATO-approved FP Courses offered by NSO.

NSO is a prestigious NATO education and training facility that provides over 110 courses annually on a wide range of topics. Each year, NSO educates more than 10,000 students from the NATO Command Structure, NATO Force Structure, NATO member countries, and NATO partners. The NATO FP courses offered at NSO, such as the P5-40 NATO Force Protection Course and the N3-155 NATO Advanced Force Protection Course (currently on pause), aim to promote a common understanding of NATO FP principles to enhance interoperability in a Joint & Combined environment.

The EAG FP Team will enhance NSO's FP courses by leveraging their expertise and network, actively engaging in course instruction, collaborating on syndicate work, and contributing to the ongoing enhancement of the courses.

The JAPCC plays a vital role as the Office of Primary Responsibility (OPR) for the FP courses. They appoint an Action Officer (AO) to supervise the course control documents, ensuring the integrity of the teaching programmes. Furthermore, JAPCC supports NSO by identifying NATO subject-matter experts who are proficient in effectively teaching the required topics outlined in these documents. ●

Deep Space Warfare – Military Strategy Beyond Orbit

A 1960s Stanford University computer scientist once said, 'we overestimate the impact of technology in the short-term and underestimate the effect in the long run'. Deep Space Warfare, by John C. Wright, runs with this idea and proposes that eventually conflict may expand deep into the cosmos with technology hardly imaginable today. Before such a scenario becomes reality, military, policy, and academic experts should carefully consider the potential consequences. Deep Space Warfare is an engaging examination of these potential battlefields in space, focusing far beyond today's Earth-centric orbital regimes. Wright achieves this by leveraging his US Air Force background and inspiration from military education institutions to inform how interplanetary warfare could look.

While this may seem like science fiction at first, his operational foresight is grounded with a realistic foundation of past and modern warfare doctrine and principles that already exist within air, land, and sea combat. Ultimately, Wright does a wonderful job in academically applying military and political concepts that span across multiple governmental realms today, such as logistics, political will, targeting, blockades, economics, diplomacy, and more to this interstellar landscape. This book is for all audiences who have curiosity about military applications to the vastness of space and/or who desire to learn about a futuristic and novel topic while staying based on practicality.

By John C. Wright; McFarland and Company, Inc; 2019
Reviewed by: Captain Lucas Stensberg, US SF, JAPCC

Modern Russian Air Power, Vol 1 – The Russian Air Arms Today

Pre-release Review-E-Version
Launch Summer 2024

Butowski's extensive knowledge and expertise in the field of aviation journalism make him the perfect author to tackle such a comprehensive and detailed project. His thorough research and firsthand experience provide readers with a unique insight into the capabilities and advancements of Russian air power. The first two volumes will serve as essential reference guides for military enthusiasts, historians, and anyone interested in the complex world of Russian military aviation. From fighter jets to transport planes, each aircraft will be meticulously examined, offering readers a comprehensive understanding of their role within Russia's air force.

The third volume promises to be a captivating exploration of Russia's air forces throughout history, shedding light on their strategic decisions, technological advancements, and contributions to various conflicts around the world. The first volume of the book will focus on various aircraft and weapons used by the Russian military, such as the Su-57, Su-30, and Su-25 attack aircraft. It also covers the conversion of the MiG-31 into a strike aircraft and ongoing projects in the Russian military, making it a must-read!

By Piotr Butowski; Harpia Publishing Verlags GmbH; 2024
Pre-release review by: Major Tamás Oszlár, HU AF, JAPCC

AIR SUPERIORITY CONNECTING THE BATTLESPACE WITH UNMATCHED CAPABILITIES THAT STRENGTHEN NATIONAL AND ALLIED-BASED DEFENSE.


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