Transforming Joint Air and Space Power

The Journal of the JAPCC

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PAGE 6

100 Years of the Italian Air Force

Interview with the Chief of the Italian Air Force

PAGE 35

Human-Machine Interface: An Evolutionary Necessity

PAGE 75

The Next 'Small Step for Man' in the Metaverse

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Editorial

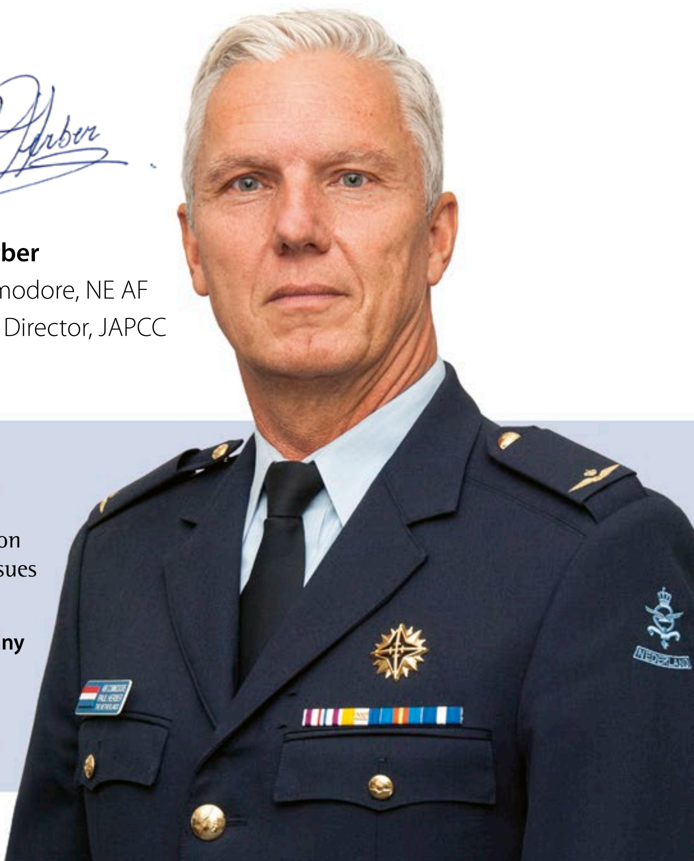
On 24 February 2022, our world shuddered with the Russian invasion of Ukraine. Directly adjacent to NATO's borders, this treacherous act should be considered a wake-up call for recognizing the dangers and threats still facing our world, and in particular our Alliance. Already under the strain of the Covid-19 pandemic, albeit waning in the last few months, our nations face extraordinary circumstances with tremendous consequences for our daily lives. All these developments bear witness to the need for maintaining a high level of cooperation and collaboration between nations. At the same time, central to achieving success is the need to keep the competitive edge that will carry us with confidence into the future. Under this backdrop, the JAPCC continues to pursue its role as the steadfast advocate for the transformation of NATO Air and Space Power.

Opening this journal edition, the Chief of the Italian Air Force, Lieutenant General Goretti, provides us with his reflections, ambitions, goals, and reports on the next-generation evolution and integration of the Italian Air Force. The 'Transformation & Capabilities' section unfolds with the 'AI-Human Symbiosis in Fighter Aircraft' article, which explores the challenges deriving from an AI-controlled aircraft. Next, 'High-Altitude Platform Systems' advocates for the development of systems to operate in the so-called 'Near Space'. The 'Good News or Bad News?' article stresses the need to frame a new generation of network-enabled weapons to maintain the ability to operate successfully in a multi-domain conflict. 'Human-Machine Interface: An Evolutionary Necessity' examines the design and development of next-generation military aircraft cockpits focused on the pilot's true cognitive capabilities. Then, 'Close Air Support C2' argues for improved and digitized communication systems to achieve accurate, timely, and responsive CAS operations. 'The Role of Aircraft Carriers in a Contested Age' article promotes the Maritime domain as the principal stage of strategic competition in the future. Closing this section, the 'Cluster Satellite Architectures' article argues for increased research, development, and fielding of smaller cluster satellites.

Under the 'Viewpoints' section, the article 'Defining the Swarm' proffers an overarching definition which accommodates all interested stakeholders. The 'Collective Defence in the Space Domain' article discusses the threats that the Space domain faces today, the potential forms of an attack in Space, and the avenues that NATO has to respond. In the 'Out of the Box' section, the 'The Next Small Step for Man in the Metaverse' article reveals the 'next big thing', the Meta-domain environment. Completing this edition is a special featured article devoted to the initial air domain-focused observations on the conflict in Ukraine and based solely on open-source information.

Thank you for taking the time to read this edition of our Journal. Also, I would like to express my sincere gratitude to all our contributing authors. We hope you will find it informative and stimulating, and we greatly appreciate any feedback you may have. I urge you to reach out and visit our website at www.japcc.org, like us on LinkedIn or Twitter, or email us at contact@japcc.org.

Paul Herber
Air Commodore, NE AF
Assistant Director, JAPCC



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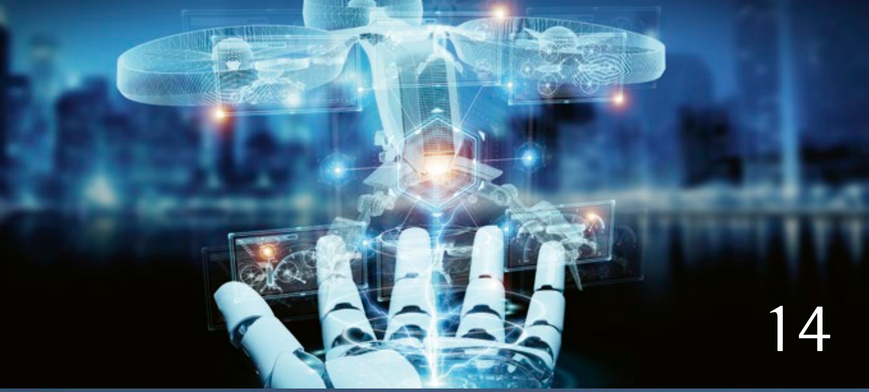

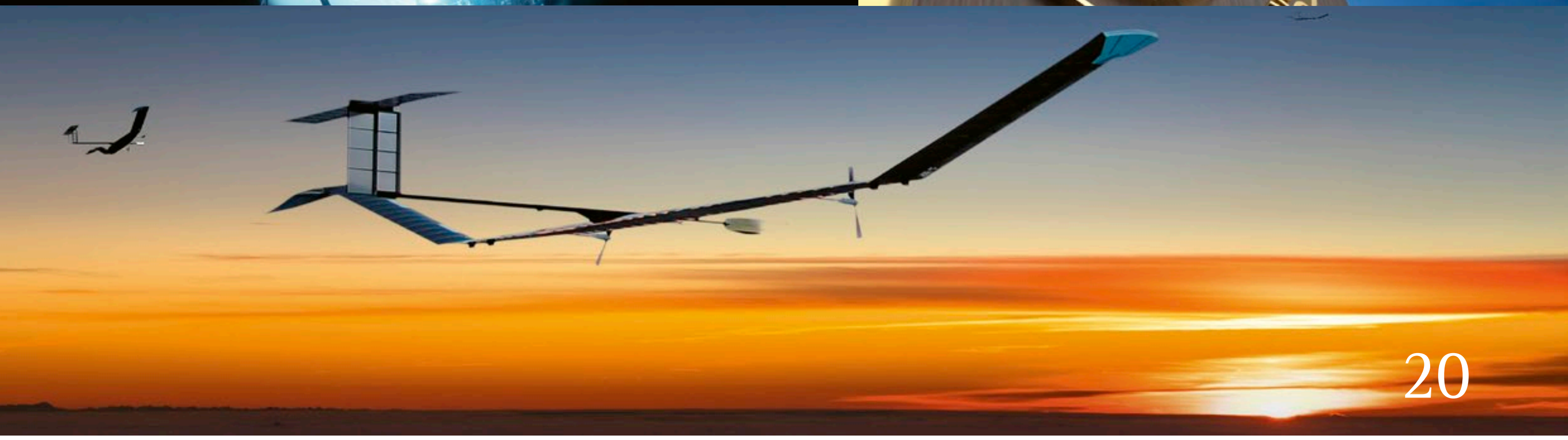

Table of Contents

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

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100 Years of the Italian Air Force

An Introspective Look over a Centenary of Tangible Relevance

The JAPCC's Interview with Lieutenant General Luca Goretti, Chief of the Italian Air Force

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'We already have the institutional duty to defend our skies; in the coming years, threats will come from much higher, but we as the Air Force will always be responsible by law to protect and defend our territory from any threat regardless of where it originates.'

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Next year the Italian Air Force is celebrating 100 years of existence. Is it getting older or younger?

Actually, both. The Air Force is now dealing, more than ever, with a complex *dichotomy*. On one side, every year our personnel are growing older. On the other side, our Air Force is increasingly embracing technology, and thus, has to invest in and rely on the younger generation that is capable of dealing with top-notch weapon systems.

In 2023, we will be among the few Air Forces celebrating a *centennial legacy*. Our responsibility for the future is to design a force model that is sustainable in the longer term and pivotal for the Alliance's defence capability. As a matter of fact and thanks to the strategic foresight of my predecessors, our Air Force is one of the strongest contributors to Air Policing, from the High North to Europe's Eastern and Southern flanks. At the same time, although a relatively small Air Component, we demonstrated how a massive airlift from Afghanistan could be handled, while operating concurrently in other theatres with our fighter force. Finally, we never stopped training highly skilled pilots at home for a multitude of different countries and services. We will successfully manage this dichotomy if, in the future, we make this *agile* and *second nature*.

Our Centenary logo represents this burst of innovation and transformation towards a new posture necessary to deal with cutting-edge technologies, as is the case with the F-35. This novel approach is aimed at shaping our organization around the *combat elements* (i.e. all the assets suitable for contested environments), and as such, they must be kept in high readiness and consistently capable of delivering the *full spectrum* of Air & Space Power, from kinetic effects to air mobility. Not an easy task, especially if we look back at more than two decades of financial cuts to a Military Instrument that deals globally with the widest and most complex domain and is also the primary enabler and synchronization tool for the land and maritime components. This is confirmed by real-life combat-proven Air Power successes in recent air campaigns, mainly due to precision strike and the high speed of intervention.

One of the dozens of events that will celebrate our centenary is the *Air & Space Power Conference*. It will be held in Rome in *May 2023* and will be a perfect opportunity to discuss, at the strategic and operational levels, how the vertical and technological expansion of the Air domain into the Space domain will affect our Force Structure by *'Reshaping Space & Time'.*[1]

Advanced flight training and staff development seem essential to an agile and technologically advanced Air Force like the one you just described. What are the main objectives you are pursuing in these fields?

One of my priorities has always been personnel training. When, as Force Commanders, we imagine the Air Component of the future – 2035 and beyond – we often talk, for example, about Multi-Domain Operations (MDO) and the ability to fuse data and synchronize the effects of the Joint Force… Well, we rarely talk deeply enough about how we generate such capabilities. There is enough debate today on what does MDO exactly mean, but no real checklist of the *skills* needed to manage them effectively. As the Italian Air Force, we are defining a journey whose destination is a Component where airmen are natively integrated with the academic and industrial worlds. We take the *'evolution trinity'* – government, academic world, and aerospace industry – very seriously. Thus, we begin this transformation journey from the Air Force Academy and the Training Institutions at all levels. Keeping this approach in mind, we are updating the syllabi and trying to give our cadets the correct tools and the necessary networks to realize something great with their colleagues from the Universities and the Aerospace companies: Officers (and NCOs) together with engineers, technicians and professors. An 'arena' where Air & Space Power innovative concepts and related technology developments spark from the same shared idea.

Likewise, we stress the importance of *decentralizing decision-making* and empowering younger echelons to suggest the best course of action. Tomorrow, operational theatres might be so complex (think of cyber and information warfare!) that only highly skilled subject matter experts might have the right tool to handle and identify a piece of information as real or fake. The *enormous amount of data* generated by the five domains (four of which are physical, one virtual and, someday, cognitive) require different levels of analysis and processing power to identify relevant data, process it, and extract potential information related to a new threat otherwise impossible to spot. In other words, automation or Artificial Intelligence must work relentlessly to identify the outlier, the glitch, so that the human operator can analyse and process only a pre-selected amount of information and focus on decision-making. In doing so, extensive study of the algorithms behind the *automation* and around concepts like 'graceful degradation' and 'automation bias' is required.

Future Forces in the field will require specific multi-domain training to cope with many inputs from multiple environments, some of which may be inexplicable


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from a single-service perspective. Hence, we are identifying and building the proper training pattern (i.e. exposure to all sensors and effectors, as well as Command and Control (C2) nodes across the Alliance's Services) to create an *all-domain ontology* that spans from the integrated planning of the operations to the synchronization of effects throughout the whole tasking cycle. These Forces have to exercise in specific training environments (focusing on C2 disruption), where they should demonstrate an unbiased and natural propensity to integrated operations.

Along this same line of thinking, we are consequently proceeding at full speed in expanding and completing the aforementioned training environment, called the *Operational Training Infrastructure* (OTI). As an Air Force, we deliver effects into, throughout, and from the vertical dimension. To remain relevant in future warfighting scenarios, we must constantly exercise our skills and adapt our *doctrine* (namely, our set of beliefs) to the changing world. The OTI is both a training environment where we develop and fine-tune our flying skills and a training posture where we begin with advanced fighter trainers (like the M-346) and continue with 5th Gen assets (like the F-35, and tomorrow, the FCAS Tempest). A huge *training arena* where operational and environmental conditions match perfectly with our next-generation training requirements.

All western Air Forces experienced significant financial cuts and, consequently, we infer a reduction in aircraft numbers. Nowadays, due to the Ukrainian crisis, the notorious 2% of GDP is not a chimera anymore: what would you ask for in case of an increased budget?

Two things. A few more *aircraft* and *space assets* to be able to deal with multiple concurrent theatres in the ever-broader spectrum of the competition-continuum and definitely, more Combat Service Support and *enablers,* including ground equipment, spare parts, integrated logistics support, and so forth.

The core strengths of an Air Force are indeed *speed, flexibility,* and *global reach*. Such abilities rely on pre-planned logistic chains and effective, operationally oriented sustainment contracts. The crisis in Ukraine reminded us, in Europe, that a 'sitting on the fence' philosophy is detrimental to a functional force structure and its ability to sustain prolonged operations in multiple Areas of Responsibility (AOR), especially for countries like Italy that have a greater footprint in defending the Alliance at home and abroad. The legacy force-on-force type of warfare has not disappeared yet, as some had erroneously envisioned. Again, new investments must focus on completing our innovation process to withstand peer competitors and make longer engagements sustainable to maintain the operational flexibility so peculiar to the Air Force.

You mentioned the core strengths of an Air Component. How does the F-35B[2] flow into this context?

The F-35B is a *niche of excellence* in terms of operational flexibility. It can access a much larger number of airstrips than the conventional variant at the cost of some capabilities (mainly related to range and landing weight). For this reason, it enables the Air Force in a specific sector of the Air Power pillars, namely the *Air Expeditionary component*. In a few words, it means that the F-35B can deploy fast, at increased ranges with tanker support, and pretty much everywhere, if we consider damaged runways, central African territories, and even highways around Eastern Europe. With such an enhanced *deployable component,* we can build a high-readiness force package comprised of both fighter and tactical assets (for instance: MC-27J for tactical C2, KC-130J for tanking in the air and on the ground, HH-101A combat helicopters with Force Protection

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and Special Forces teams, etc.) capable of autonomously executing rapid, *in & out* type of missions all around the Mediterranean region, following our Ministry of Defence defined AORs and even in non-permissive environments. This would also include the possibility of supporting a major Air Force package, composed of the full spectrum of Air Power assets, deployed on a Forward Operating Base near an Anti-Access/Area Denial (A2/AD) boundary otherwise not accessible by other forces, like ships or conventional support aircraft, which can become easy 'targets' in such an environment. It matches seamlessly with the *Agile Combat Employment* (ACE) concept, which entails the requirement to 'shift operations from centralized physical infrastructures to a network of smaller, dispersed locations that are defensible, sustainable and relocatable'.[3] This is an entirely different concept from that of Air Mobility – which we still provide – involving strategic ranges, greater take-off weights, no kinetic effects, permissive environments, and so forth.

We spoke about training, financial perspectives, and the F35B's unique capabilities. Let's move into the future: can you tell us what to expect in the next decades?

Wishing to complete a survey of Italian Air Force weapon systems by around 2040, we cannot avoid starting from the two main baskets into which these capabilities are functionally divided.

On one side, we have the so-called *'combat elements',* further divided into fighters, Remotely Piloted Aircraft (RPAs), and multi-crew aircraft (fixed- and rotary-wing). I am proud to say that, with a singular vision, we have designed a fully low-observable fighter force comprised of F-35As, F-35Bs, and the new 6th Gen FCAS Tempest, which will gradually replace the Typhoon fleet around 2040. Having in mind the Ukrainian crisis and the threat posed by the surface-based missile systems, that we are now all familiar with, our Force design is the tangible result of the strategic foresight of my predecessors. Coupled with the substantial force offering that Italy constantly makes available to the Alliance, our Air Force will constitute an ever-stronger Military Instrument of Power available to the Italian Government. RPAs will consist of the MQ-9A Predator B (new Block 5 with kinetic capability), the European MALE, and Leonardo Falco X-Plorer drones. The multi-crew assets spanning all NATO Main Capability Areas are the (K)C-130J(-30), the (M)C-27J (different variants), and the G-550 (both C2 and Intelligence, Surveillance and Reconnaissance (ISR) variants). Helos will be the HH-101A and possibly a version of the Future Vertical Lift, still to be defined, but aimed at bolstering our agility and flexibility in future scenarios.

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On the other side, the *non-combat,* but equally vital *elements* fulfil a variety of missions both for the Air Force itself and for different services and agencies. We also have State transport assets, different helicopter versions dedicated to Search & Rescue missions, passenger transport, medical evacuation and firefighting (A-139), and fixed-wing passenger aircraft like the Piaggio P-180. Finally, we have other excellent systems, like the aforementioned M-346 and M-345, the brand-new Light Utility Helicopter A-169, and a series of gliders. Overall, a cutting-edge set of weapons systems that make us proud of our *centennial legacy* in military aviation.

Obviously, those are the flying assets. However, other elements must be recognized since they are equally important in terms of contribution to Air & Space Power effects: air-defence systems from short to medium and long-range and even upper layer (protection against ballistic missiles and hypersonic weapons is a must!), Force Protection and Special Forces (supporting Air Force specific requirements), suborbital vectors and stratospheric ISR platforms, datalinks, cyber avionics, complex weapons, disruptive technologies, and so on.

To conclude, what are your thoughts regarding the forthcoming celebration of 100 years of the Italian Air Force?

In closing, I would take this opportunity to remind our readers that the Air Force has a natural vocation toward Space. We already have the institutional duty to defend our skies; in the coming years, threats will come from much higher, but we as the Air Force will always be responsible by law to protect and defend our territory from any threat regardless of where it originates. For this reason, we have in place a clear strategy that envisions cooperation in human space flight, suborbital flights, and quick satellite replacement. Future airmen will grow up and develop in a technologically advanced environment and be at the forefront of this new world. As leaders and instructors, we need to dare and adapt alongside this new generation. We need to change how we work to deliver capabilities on time or lose. We need to modify our skills quickly enough to sustain these new technologies.

I feel responsible for giving the people I represent all my trust, because I am positive they have the hallmark to succeed.

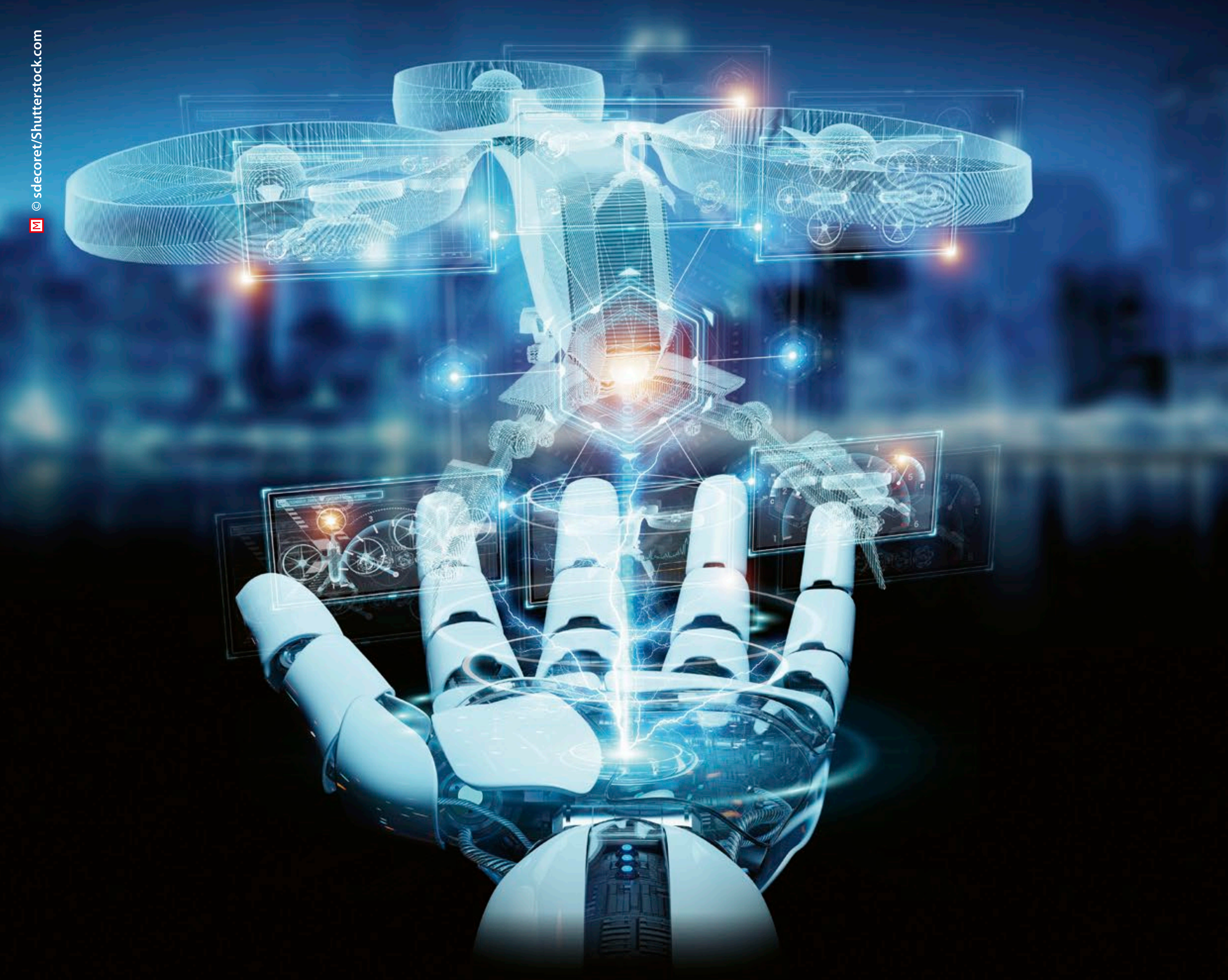
Sir, thank you for your time and your comments.

1. The 2023 Italian Air Force Conference theme is 'Reshaping Space & Time'.
2. Italian Air Force is the only European Air Force owning both variants of the jet, conventional and Short-Take-Off and Vertical Landing (STOVL).
3. See Air Force Doctrine Note 1-21, 'Agile Combat Employment', USAF, 1 December 2021.

Lieutenant General Luca Goretti

graduated from the Italian Air Force Academy in 1984. After the pre-operative course on the G-91T, he was assigned to pilot the Tornado aircraft. In 1986, he was posted to the 36th Wing at Gioia del Colle AFB, where he took part in flight operations in Albania and Bosnia, within the framework of NATO operations in the former Yugoslavia. In 1998 he was assigned to the Flight Safety Inspectorate. During the NATO Allied Force Operation in Kosovo, he was posted to the NATO HQ Media Operations Centre in Brussels as Italian Military Representative. From 2003 to 2005 he commanded the 32nd Wing at Amendola AFB. In February 2008 he was transferred to the Italian Defence Staff HQ to assume the appointment of Deputy Chief of the Planning, Programming and Defence Balance General Office. In February 2010 he became Deputy Chief of the Cabinet of the Minister of Defence. In 2015, he was promoted to the rank of Major General, becoming the Defence and Defence Cooperation Attaché at the Italian Embassy in Washington DC. In 2018 he was promoted to the rank of Lieutenant General and in February 2019 he assumed the appointment of Italian Air Force Deputy Chief of Staff. Since 31 October 2021 he is the Italian Air Force Chief of Staff.

During his career, he has acquired more than 2,900 flying hours, more than 2,000 being on the Tornado.



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Artificial Intelligence – Human Symbiosis in Fighter Aircraft

End of the Fighter Jet Era or a New Evolution?

By Lieutenant Colonel Rafael Ichaso Franco, SP AF, JAPCC

Introduction

'The fighter jet era has passed.' These words were famously spoken by Elon Musk at the 2020 Air Warfare Symposium when prompted to describe the future Air Domain.[1]

Musk's position appears to be supported by the Defense Advanced Research Projects Agency (DARPA) Alphadogfight (ADT) demonstrations.[2] During ADT, several Artificial Intelligence (AI) projects faced off against each other in a dogfight tournament. The winning AI then went face-to-face against a human fighter pilot. While DARPA asserts the competition intended to develop AI processes supporting human pilots in a human-machine symbiosis,[3] the result could not have been worse for the pilot himself. The human lost every engagement against the machine and lost quicker than the AI's previous machine adversaries.

It is also worth considering how a Beyond Visual Range scenario – in which the computation of distances, knowledge of the relative position of aircraft, relative heights, speeds, and weapons all have to be done at very high speeds – would have turned out. Considering the complexity of air-to-air tactics and the prominent role of deception and electronic warfare in their conduct,[4] the result might have been even more alarming.

Nevertheless, many aircraft manufacturers continue to develop manned combat aircraft.[5] Even the cost-driven commercial airline sector is unlikely to replace human pilots.[6] Furthermore, albeit western 5th Generation fighters are all single-seat aircraft, even for training purposes, two-seat designs are back on the table. Recently, images have surfaced of the Chinese 5th Generation J-20 fighter[7] in a two-seat configuration, and Sukhoi is contemplating a two-seat version of its Su-75 Checkmate.[8] The reasons behind the return to two-seat designs remain opaque, but given the complexity of current air operations and the anticipation of more complex Multi-Domain Operations (MDO), the next generation may benefit from a Weapons System Officer.

Alternatively, DARPA's Air Combat Evolution (ACE) programme envisions a middle ground where human pilots trust the AI to control the aircraft while they command the mission through tasks requiring human judgement or responsibility such as deciding on the engagement strategy, selecting and prioritizing targets, and determining the best weapon or effect.[9]

The future will almost certainly include the AI advantages asserted by Musk and anticipated by DARPA, but should they accompany or replace the human pilot? Numerous challenges remain. This article will highlight the most important.

Challenges and Considerations

Machine-Learning Process

The most common machine learning method supporting AI is Reinforcement Learning (RL),[10] which enables a computer algorithm to learn by itself from past events. The machine uses a reward system to discriminate between successful and unsuccessful moves, and it can be performed quickly, in an unguided way, without human interaction. At the same time, a human can also point out mistakes and help to reinforce future courses for the machine to seek success.

'Future fighter aircraft…will experience dramatically increased pilot workloads. AI has to play some role in managing this workload.'

Reward Shaping[11] is another machine learning technique that complements RL by accelerating learning outcomes through assigning relative values to transactions. This concept incentivizes AI to move to a higher-paid status by exploiting what it has already learned about the 'value' of its previous choices. This valuation enables the AI to conduct risk versus reward calculations while exploring a range of actions in pursuit of higher rewards. The objective is to reach a good trade-off after exploring all the possible solutions and rewards.[12]

An additional advantage that may accelerate the learning process is that AI systems can build on other AI systems' experience, using additional machines to train within the desired network without human involvement and transferring gained knowledge to a target machine. Several simulators, each applying different tactics, could dramatically accelerate the learning process.

However, machine learning should not be seen as a panacea. It is still highly dependent on software design, algorithms, and data choices. Incomplete or insidious information incorporated within the machine learning technique can lead to significant deficiencies or errors in the learning process. As a result, AI could make ineffective or dangerous decisions.

Control of the Aircraft

Although the trend is for AI to aid the pilot only if the ACE programme shows that AI flies better, how will both options be merged in a real fighter aircraft?

One option is for the plane to be controlled by a human pilot and only advised by the AI, at least until the machine recognizes a critical risk and assesses that it can respond faster or better than the human. Should the human pilot always retain control over this decision or should the AI be authorized to take control without pre-authorization to ensure mission success or aircraft survival? Similarly, should the pilot take all weapons employment actions knowing that his reaction time implies the loss of critical seconds that could compromise positioning or shot opportunity?

Additionally, not being at risk of losing consciousness at the extremes of the aircraft's manoeuvring capabilities is one of the compelling advantages AI has over a human pilot. While it is anticipated that AI could incorporate data on the pilot's health status, the only way to gain an advantage against an adversary could be at the expense of the pilot's consciousness. With an unconscious pilot, should the AI employ weapons autonomously?

Furthermore, since fighter aircraft traditionally operate in two- or four-ship formations, decisions about human versus AI control will affect both the individual aircraft and the entire flight. Consideration is required for how an AI-controlled aircraft communicates with the other formation's aircrews and whether it is done via datalink, voice, or both. Given the possibility that some, but not all, aircraft in a flight are under AI control – and potentially with unconscious pilots – should the control of the entire formation be delegated to AI or should it be transferred to any conscious pilot?

A more straightforward option is to constrain the AI into an aide role to provide the appropriate information at the precise moment to avoid saturation and, perhaps, in particular circumstances such as when needed for survival, take command of the plane as the extant fly-by-wire systems do when angle-of-attack limits are exceeded or in certain out-of-control situations.

As of today, due to its considerable complexity, the most likely evolution is for AI to simply help the pilot. However, as technology evolves quickly we should certainly not avoid AI's support, especially knowing that potential adversaries will use it extensively.[13]

Ethics

Many authors have written about the moral and ethical aspects of robotic-autonomous and AI-controlled weapons systems and have explored whether we should allow machines to make life or death decisions regarding humans. A particular case to assess ethically is that of AI overriding the control of the human pilot. Some consider that a fully developed AI will be responsible and legally accountable for its decisions and the consequences. In contrast, others believe that at least one human must retain responsibility and legal accountability.[14] Who would be responsible if an AI-controlled aircraft makes an error that leads to the loss of human lives? It could be considered that the human pilot, even if he might have had no chance to intervene or cancel the action, or even the programmer but, most probably, the commander that ordered the mission will be the responsible one.[15]

Accurate Intelligence and AI-Derived Tactics

Intelligence-derived data will provide the basis for the AI learning process. It is anticipated that AI will process all sensor data available to an aircraft, its flight members, and perhaps a much broader cloud-networked system of systems. In real time, this will support decision advantage for the individual aircraft and enable a significant ability to propose and evaluate tactics during test and evaluation events.[16] However, just as data alone does not equate to accurate intelligence, data alone will not create new tactics either. Human judgement interprets the data, infers adversary capabilities and tactics, creates the test environments, and evaluates the results. The accuracy of these human choices will inevitably impact AI-derived tactics just as in conventional tactics development. Here, AI's ability to run massive sets of simulations should be leveraged to provide a wide range of potential options to deal with unforeseen adversary capabilities and tactics.

Where Will AI Be Located?

When we think of AI-Human symbiosis in a fighter aircraft, R2D2, Luke Skywalker, and the X-Wing fighter from Star Wars inevitably come to mind. However, where will the AI be in real fighters? Will it be on the aircraft or in a cloud? Would the cloud-AI overcome the communications latency to gain an advantage over a human in a dogfight? Dislocating the AI or the pilot implies risks that should be minimized, knowing that advantages in communications are never absolute nor permanent.

To set expectations, it should be noted that ADT used a rack of computers and servers to process live data provided by the human-piloted fighter. Such computing power and the enabled data supremacy cannot currently be incorporated in a fighter jet.

How Will the AI 'Feel'?

In the ADT contest, the human pilot used a high-fidelity Virtual Reality system to track the AI-piloted adversary aircraft visually. However, since the digital smart model used in the competition lacked sensors, the AI received all adversary data as a direct input, relieving the more complex tasks such as sensing and interpretation. The use of accurate data about the opponent's flight parameters brought a significant advantage to the machine. This data in actual combat is not easy to obtain and, when gathered, is not always accurate. Human pilots have

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to infer an opponent's parameters, complicating the interpretation and the decision-making. AI agents will have to do the same.

To that end, AI will need more than just the information available to the pilot (including radar, warning receivers, infrared sensors, and data links) to 'feel' and maintain situational awareness. AI will need a suite of visual sensors similar to those incorporated in self-driving cars to enable equivalent visual lookout as is currently accomplished by human pilots. While it is anticipated that AI will be faster at interpreting properly integrated sensors – no small feat in itself – it remains to be seen how well the AI will respond to unanticipated or anomalous situations 'where feeling or intuition' is required. This will be assessed in the final step of the ACE programme, the real dogfight between two fighter jets, one piloted by a human and the other by AI.

Conclusion

Future fighter aircraft, especially those envisioned to be employed alongside AI-piloted drones/wingmen and operated in an MDO environment, will experience dramatically increased pilot workloads. AI has to play some role in managing this workload.

However, given the range of possibilities, it is difficult to imagine a human managing the air battle as a passenger on an AI-piloted aircraft, while the AI autonomously manoeuvres the aircraft into a firing position and then transfers control of the weapons to the pilot or fires missiles without human authorization. It is easier to envision a pilot flying the aircraft with AI support to improve the accuracy and timeliness of tactical information and provide threat diagnosis, warnings, and possible defensive manoeuvres, like the use of countermeasures or other tactical options.

While it is reasonable to consider that AI-Human teaming will be inferior to what an adversary could do with unfettered AI, it remains to be seen whether AI can replace the human pilot across the entire spectrum of future scenarios.[17] Many technological, ethical, and practical challenges remain. Nevertheless, it is anticipated that AI-Human teaming will provide a more resilient and effective approach for future fighter aircraft, but only if an optimized AI-Human symbiosis is prioritized and achieved.

Admittedly, the future of fighter combat operations will keep evolving and Elon Musk's prescient warning regarding the end of the crewed fighter jet age could not be farther from the truth.

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Lieutenant Colonel Rafael Ichaso Franco

joined the Spanish Air Force in 1993. He was assigned to the 15th Fighter Wing from 1998 to 2005 and 2007–2009, and in between was an Instructor Pilot in the Fighter Weapons School, 23rd Wing. In 2009, he was assigned as Flying Instructor at the Air Force Academy. From 2013 to 2016, he served in NATO HQ AIRCOM, Ramstein, Evaluations Division as Flying Forces Project Officer and evaluator. He attended the Armed Forces Joint Staff Course in 2017. Prior to his assignment to the JAPCC, he served in the Spanish Air Combat Command.

He has more than 2,700 hours flown in C-101, F-5, and EF-18.

Figure 1: Example of a HAPS HTA: ZEPHYR is a lightweight UAV developed by AIRBUS.[1]

High-Altitude Platform Systems

Alternative, Supplement, or Competition to Satellites?

By Lieutenant Colonel Heiner Grest, GE AF, JAPCC

Introduction

Since Space is an above-average growth market, it is becoming increasingly contested, congested, and competitive. This statement is broadly known and accepted; however, it applies mainly to Low Earth Orbits (LEO).[2] These orbits are very popular for a variety of space actors which are operating a broad range of commercial, governmental, and military application satellites. To offset the constantly increasing population of satellites and avoid overcrowding, we have to consider using the areas above, like the Medium Earth Orbit (MEO),[3] or below LEO.

This article outlines the essential characteristics and the suitability for military purposes of those systems that may operate below LEO and above the currently used airspace, namely High-Altitude Platform Systems (HAPS). These systems may seem all the more attractive since large constellations of CubeSats[4] have recently begun to be deployed in LEO, leading to a further increase in the satellite population.

The Karman-Line, at 100 km, is generally accepted as the boundary between Air and Space. The upper limit for civil air traffic and most military aviation is 18 km (a few Unmanned Aerial Vehicles (UAV) reach

heights of 20 km), and the lowest practical orbit for satellites is at an altitude of about 160 km. A part of the area between these boundaries, from 20 to 100 km, is labelled as the 'Near Space'.[5] This whole area is mainly unused and underexplored, and is primarily used by transiting orbital rockets and, sporadically, for scientific purposes by suborbital and trans-atmospheric rockets. This area may be increasingly utilized for space tourism and by hypersonic missiles in the future. Thus, the challenge is to make this large and almost untouched space usable to humans. Interested actors have already started to develop new technical artefacts to employ in Near Space, with the intent to generate specific advantages over aircraft or satellite use.

Objects flying above typical aeroplane altitudes and below space-based objects do have many notations, like HAPS, Balloon Born Objects, Pseudo Satellites, Stratospheric Satellites, High-Altitude Airships, Sub-Orbital Platforms, Stratospheric Platforms, Stratospheric Airships, High-Flying Drones, Stratospheric UAVs, and others. These terms are mixing several different types of flight systems, each characterized by some essential (condensed) specifications:

- *Airplane:* heavier than air, dynamic lift, air-breathing engines, highly manoeuvrable.
- *Airship:* flying with materials lighter than the surrounding air, manoeuvrable.
- *Balloon:* flying with materials lighter than the surrounding air, not manoeuvrable.
- *Satellite:* operating in a vacuum, fuel and oxidizer on-board, orbiting, very limited manoeuvrability.

The most commonly used term is HAPS, an all-encompassing term that does not emphasize any particular specification. It includes all different types of vehicles expected to fly in Near Space from a few minutes or hours to weeks, months, or even years. Due to their insufficient speed and height to achieve an orbit around the earth, their flights are generally labelled as sub-orbital flights.

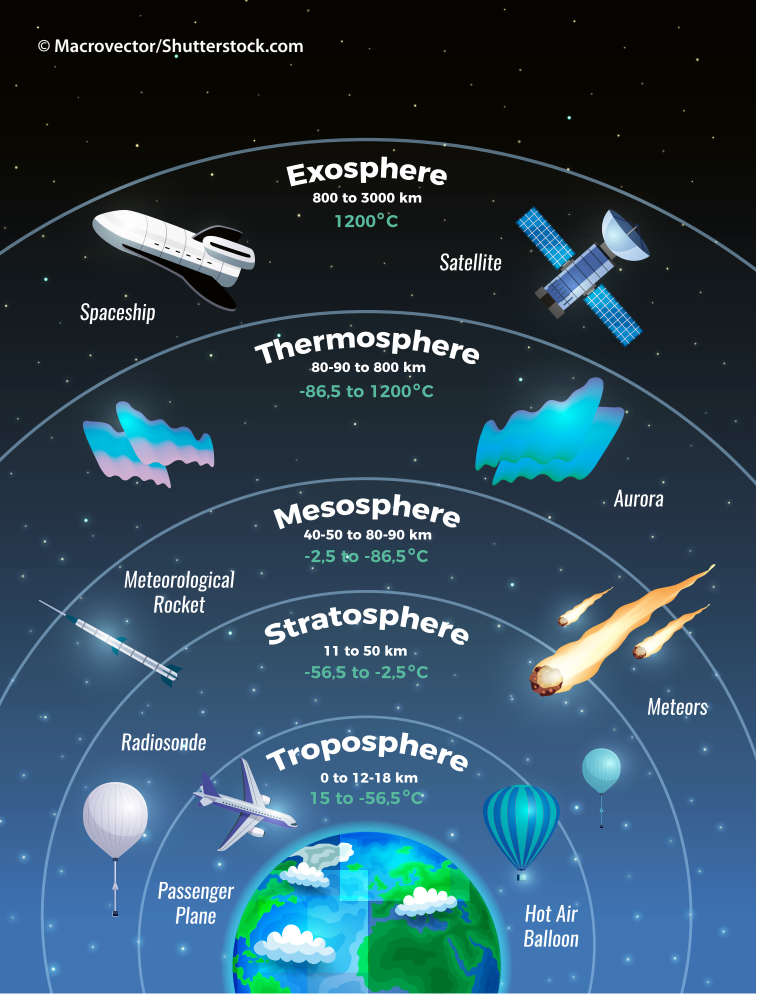

Figure 2: The area above earth.

The 18 to 160 km altitude range is not a consistent zone with constant parameters. It is subdivided into different layers (Figure 2), each imposing requirements on a potential flight object due to its specific physical conditions.

Main HAPS Characteristics

The idea behind HAPS is not new, but modern technological developments make them presently achievable. For several years now, technological developments have progressed to the point where the first prototypes were ready for presentation. However, these models were mainly experimental and, currently, can only achieve their high-performance criteria under optimal test conditions.

HAPS can be described as crewed or uncrewed flying objects, positioned in the Near Space to take advantage of the weak stratospheric winds and the high solar energy, which can operate in these areas without interfering with current aviation.

There are two main versions of HAPS: Lighter Than Air (LTA), like balloons or airships, and Heavier Than Air (HTA), like aeroplanes. Both types have many common technical features; the specific differences are due to their construction features.

Like any aircraft or satellite, all HAPS are complex systems with inherent challenges related to weight or power and energy supply. The significant progress achieved in the development of emerging and disruptive technologies indicates that HAPS are now feasible. The use of lightweight but stable materials, resistant to solar and ultraviolet radiation, and the miniaturization of components are keys to success. The low air density in the stratosphere (at 20 km is merely 7% of the pressure at sea level) causes lower lift; therefore, the tremendous challenges remain to be balanced with the aerodynamics. However, take-off and landing of HAPS take place under normal ground conditions.

A lightweight airframe imposes limits on the energy source available to the HAPS and its method of supply. The first choice is to use robust solar panels and state-of-the-art batteries to produce and store the energy generated during the day for night operations, at least for the payloads and sometimes also for the platform's propulsion. The alternative is the use of fuel cells. In this case, by reducing the influence of weather and eluding the fluctuating solar energy, a better ratio of energy production versus consumption can be leveraged. However, during fall, winter, or at high latitudes the reduced amount of solar radiation imposes some additional limitations. Overall, the operational capabilities of the payload are dependent on the maximum possible weight. Therefore, a modular design is preferred.

There are additional challenges to be addressed. Thermal control must be considered, even if the differences between day and night or at various altitudes are not as extreme as in Space. The use of gases for lift implies their expansion at greater heights and requires a corresponding advanced structural design of the hull. General aspects of flight management must be considered, like autonomy, semi-autonomy, or manual control. The launch and recovery phases

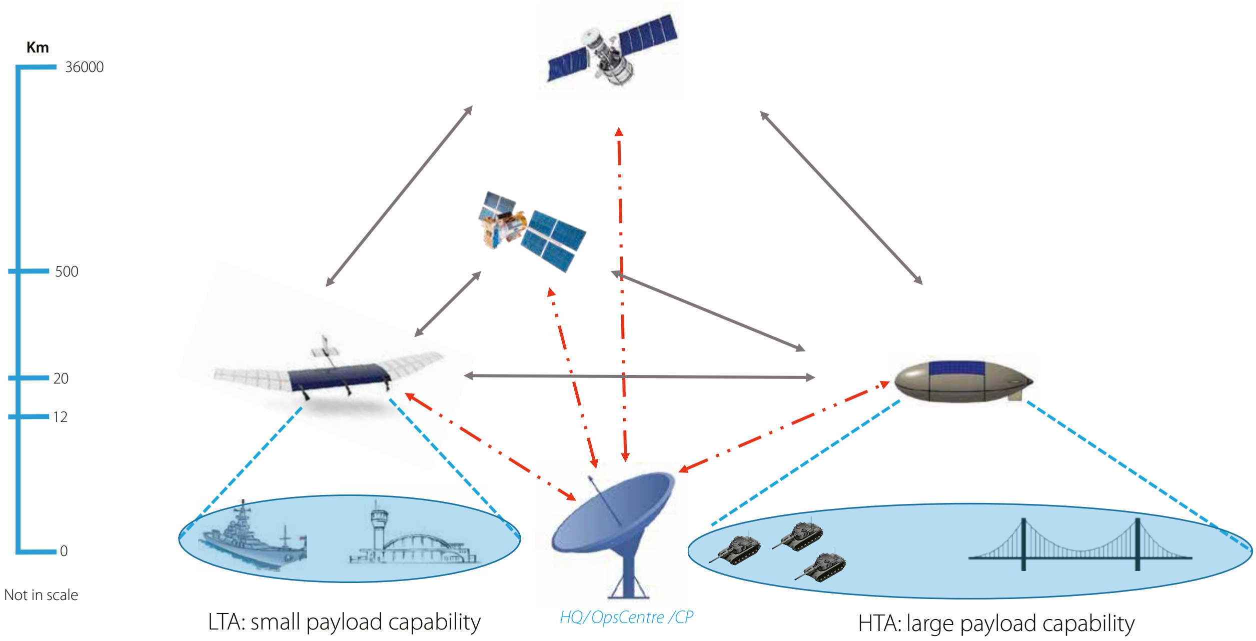

Figure 3: HAPS Concept.

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require appropriate ground infrastructure and, finally, the integration of laser technology can achieve the best results, in quality and quantity, for the HAPS' communication systems.

All sub-systems require strong reliability for long-duration flights over weeks or even longer timeframes.

Main HAPS Applications and Services

Generally, HAPS offer applications and services that can be provided by aircraft or satellites as well. However, their advantages stem from the operating altitude and the specific design, the result of combining the flexibility of aircraft (including UAVs) with the endurance of satellites.

Today's application developments mainly focus on overhead communications, telephone and internet services, or broadcasting radio stations.[6] Earth observation, including weather observation, and remote sensing are the other main areas of application. To a lesser extent, they can also serve as platforms for Position, Navigation, and Timing, augmentation, research, or scientific experimentation.

Finally, they may be employed as relay stations connecting various partners in the Air, in Near Space, and in Space.

HAPS-Satellites Comparison

HAPS are equally capable of performing some of the satellites' services. They can provide continuous long-term services by staying in the same position over a given point or area for weeks, months, or even longer.

Flying at a much lower altitude than satellites, HAPS are capable of covering a specific area much more effectively. They may operate in smaller or wider areas of interest and adjust their flight patterns accordingly in reaction to the experienced challenges (e.g. following weather patterns, like hurricanes) or missions (e.g. following migration movements, like refugees or cattle herds). A satellite cannot change its orbit. HAPS can stay permanently over an area, whereas LEO satellites can only stay for short periods (minutes); a return to the area is dependent on the revisit time and may take hours or even days. For permanent observation of an area a satellite constellation is required, leading to increased costs. Ground-level inclement weather is only a limited constraint for HAPS, as they can be easily manoeuvred.

Generally, HAPS can accommodate a broader range of payloads, making it easier to replace its sensors and adjust to particular tasks. On short notice, they can be landed for maintenance, refuelling, or repairs.

Their employment at lower altitudes brings advantages in telecommunications, due to the shorter time delay in up-/downlink with less latency, as well as communication and data transfer in real time with higher reliability. This results in lower on-board power consumption compared to satellites. In addition, the interference commonly caused by obstacles, like buildings and ground elevations, is less expected due to lower disturbances.

HAPS and their specific payloads have comparatively lower production and launch costs, whereas deploying a satellite requires significant time and financial resources. Thus, HAPS are rapidly constructed, deployable systems providing faster availability. Some ground infrastructure is necessary for take-off and landing, but less than required for rockets or aircraft.

Currently, with operating zones outside of controlled airspace, it means operating in areas that are not regulated. However, generally accepted legal issues must be observed, as they would be in controlled airspace, whereas for outer space there is an insufficient number of regulations.

LTA and HTA seem unreliable under extreme weather conditions (e.g. violent rains or heavy storms); however, future technical advancements are expected to overcome these limitations. Other disadvantages relate to the absence of international regulations for airspace control of the HAPS altitude bands and the well-known vulnerabilities of lightweight vehicles.

To summarize, the main benefits of HAPS are the implementation of modern technologies with shorter development cycles and at lower costs, the reduced launch requirements and ground infrastructure, and an increased ability for maintenance or upgrades. It is worth mentioning that HAPS have a minimal ecological footprint due to their low fuel consumption given their long endurance.

HAPS Development Status

Within the last decade, the number of satellites and Space debris in LEO[7] has increased considerably mainly due to new initiatives of deploying mega-constellations of small satellites, like the well-known forerunners OneWeb[8] and StarLink.[9] While StarLink is already available in select regions and OneWeb is expected in 2022, the development of HAPS has been left behind.

Various technical approaches are currently being proposed and tested, either in the form of specific test models or prototypes (see Figure 1 on page 20 and Figure 4 on page 25).

Currently, small-satellite constellations enjoy considerably more public attention and, as a result, further investments in HAPS may be less attractive. However, the specific HAPS advantages must be properly assessed to avoid wasting any opportunity that may maintain or increase NATO's overall military edge.

Options and Relevance for Military HAPS

The main HAPS benefits, closer proximity to earth than satellites and increased loiter time over a specific area than aircraft, should be of interest to the military. Therefore, the question is whether these systems can provide a competitive military advantage. Historically, soldiers understood the advantages of the 'high ground', thus promoting corresponding technical developments, such as balloons, airships, aircraft, and satellites.

The effectiveness of the new class of CubeSats in very low LEO has yet to be proven, as the individual satellite is over an area of interest only for a very limited time and a transfer of tasks must be made to another satellite in the constellation.

All described advantages and disadvantages of HAPS not only apply to the military but, additionally,

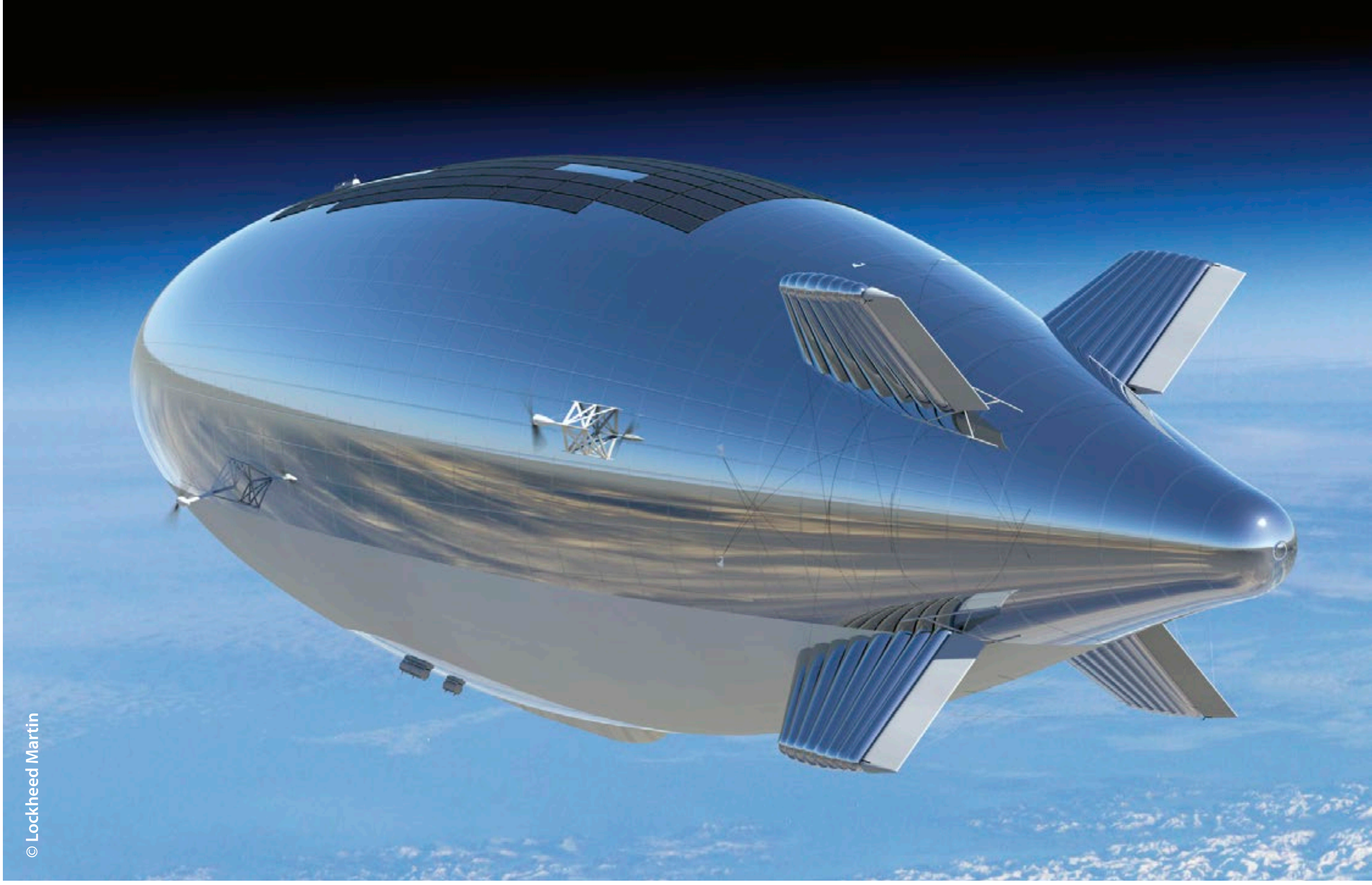

Figure 4: Example of a HAPS LTA: ISIS (Integrated Sensor is Structure) was a joint Defence Advanced Research Projects Agency (DARPA) and US Air Force Science and Technology (S&T) programme.[10]

survivability against adversary air defence is required. Therefore, it may be of little military value against a peer or near-peer adversary due to their inherent vulnerability. Nevertheless, their practicality is still valid for expeditionary operations, out-of-area deployments, or disaster relief operations.

Due to their flexible, timely, and rapid deployment, HAPS may be the best available option in the early stages of an operation or for short-term deployments. In these situations, they can be used to provide situational awareness over the battlefield wherever satellite coverage is lacking. Since they require less ground infrastructure, which is typically targeted during civil unrest, civil war, or disasters, these systems offer greater flexibility than traditional aircraft, especially since HAPS' dedicated ground infrastructure is usually highly mobile.

In addition, they can be beneficial at the tactical level since, normally, a regional commander does not have command or control over satellites. On the other hand, they must be moved to the theatre of operations and, therefore, are not normally available during the planning phase.

HAPS can be a replacement or a back-up for tactical reconnaissance aircraft, because they can remain outside the range of enemy air defences, and serve as a relay between satellites and terrestrial systems, like for beyond line of sight UAVs operations. They may be a solution to close those capability gaps caused by either the unavailability of forces or the geographic limitations in mountainous or urban areas.

Their primary military uses may be in support of the communications sector to boost data exchanges (including broadcast and relay), and to provide an additional component within integrated networks or cloud services, as well as support to Intelligence, Surveillance, and Reconnaissance tasks. Additional services could be provided within the scope of electromagnetic operations, like communications jamming or jamming of Global Navigation Satellite Systems.[11] In particular for communication services, HAPS can be in competition with, but also complementary to, wireless terrestrial communication services and LEO satellite constellations. Their application is most advantageous in those rural or mountainous areas lacking proper satellite coverage.

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With their stand-off benefits, HAPS could provide additional support for the targeting process. In general, an object flying in Near Space may benefit from the particular advantages of both space flight (overview) and aviation (flexibility). The stratosphere gives a better vantage point for a much lower price than aeroplanes and satellites. HAPS may be the link between near-earth flying objects and the satellites orbiting in Space and may supplement terrestrial and satellite-based services, like communications and earth observation.

Today's HAPS developments are mainly generated by commercial entities for commercial, civilian, and scientific use. Similarly, LEO constellations and their applications and services are currently provided by a few civilian satellite manufacturers, whose services can be purchased for military purposes.

In principle, HAPS can be a path to greater flexibility at lower costs, so a potential future use for military purposes must be considered as well. In this context, their technical performance should be carefully observed, their applicability for military operations analysed, and global developments monitored to avoid strategic surprises. For that reason, it may be worthwhile for NATO, as well as allies, to invest in researching the military advantages of these technologies. ●

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Lieutenant Colonel Heiner Grest

is currently the acting Branch Head of JAPCC's 2020 established Space Branch. He began his military career in 1982 as a conscript. Throughout his career, he has been working in various command and staff positions in Ground-Based Air and Missile Defence and diverse national staff positions. He was deployed to the NATO mission in Afghanistan at ISAF HQ. He holds a diploma in Business Administration from the Bundeswehr University Hamburg.


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Good News or Bad News?

Embryonic Development of Network Enabled Weapons

By Lieutenant Colonel Francesco Esposito, IT AF, JAPCC
By Mr Adam T. Jux, BA, Civilian Targeting Consultant

In the past few decades, the way we have understood conflict and war has seen a tremendous change. War had traditionally been understood as armed physical violence. Today, global security challenges are changing faster than in the past. Adversaries are more adaptive and able to counter their opponents from the five recognized domains: air, sea, space, land, and cyber.

All modern forces involved in military operations are now more interconnected, mutually dependent, and challenged. The ability to operate is questioned by the rapid proliferation of advanced and emerging technologies. These technological innovations, and the ever-growing dependence on the electromagnetic spectrum are affecting military operations, which requires an ever more careful examination on how forces will sense, plan, decide, and act coordinated across all domains in the future.

The purpose of this article is to frame the new generation of Network Enabled Weapons (NEWs) into a present-day multi-domain conflict, identifying strengths and weaknesses, and providing conclusions and recommendations. To achieve this aim it is essential to briefly introduce the concepts of Information Superiority, Multi-Domain Operations (MDO), and Command and Control (C2) networks in modern warfare.

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Definition of Information Superiority

All elements of intelligence involved in a conflict or operation collect vast quantities of information.

The advances in Information Technologies (IT) and the ability of modern military forces to take advantage of these opportunities, are significantly altering the nature of the conflict in which we expect to be involved in the future.

Specifically, IT changes the nature of our mission, the battlespace in which we operate, our adversaries' capabilities, our ability to sense and understand the battlespace, the capability of our weapons, and, perhaps most importantly, our ability to conduct C2.

Developing and analysing such a large quantity of data is a challenge, especially when taking into account the multiple levels of security at which these systems operate.

Information Superiority, which is defined in the Joint Publication 3-13[1] as 'the ability to collect, process, and disseminate an uninterrupted flow of information while exploiting and/or denying an adversary's ability to do the same', is the key word.

Achieving a position of Information Superiority in military operations, implies the ability to protect your collection, processing, and dissemination capability in an uninterrupted flow of information while exploiting and denying an adversary's ability to do the same. The enormity of this process is even more enunciated when, with the advancements in technology, the information being collected still exceeds the physical processing capability. Every asset has a sensor and this will only increase exponentially.

Multi-Domain Operations

The relationship between Information Superiority, the high level of shared battlespace awareness, and the necessity to operate jointly in all domains brings together a new warfighting concept known as MDO. By synchronizing global and local systems and crucial data sources with innovative simplicity, MDO presents a complete picture of the battlespace allowing warfighters to take fast decisions to steer actions. The ability to do it quicker than your opponent will allow NATO to achieve information superiority, leading to increased battlespace awareness to gain the initiative.

The new MDO contribution to the battlespace is a combination of physical and electromagnetic common operational pictures, enhanced by exploited cognitive applications and artificial intelligence. It is designed to detect [sic war] emissions, optimize Intelligence, Surveillance, and Reconnaissance (ISR) sensor collection, and autonomously update aircraft and weapons routes based on threats.[2]

New C2 Network

Understandably, a new operating concept needs a new joint C2 structure.

The new C2 framework requires secure, reliable, and affordable communication structures in order to integrate platform sensors, data, and operators (including weapon systems and decision-makers) in a contested, lethal or non-lethal electronic warfare environment. It will require a more complex Data Exchange system than the current formatted messages and, therefore, there is a need to devise a brand new network or improve an existing one. We must be mindful that many of the communications systems that we utilize today as a coalition are particularly dated. Nations must embrace a mindset of flexible procurement to ensure connectivity with our partners.

Network-Enabled Weapons

The need to ensure that all single systems are well integrated to benefit from this concept is shifting, more than ever, with military investments focusing towards increased network integration, data fusion, and NEWs.

NEWs represent an emerging class of Precision-Guided Munitions (PGM), which are able to integrate and share information between platforms and systems. They differ from the standard operational weapons by their enhanced post-launch C2 facilitating attacks on fixed, moving, and time-sensitive targets within moments of their detection and under any weather condition.

The ability to find, track, and engage a target will become faster in the future, as will reports on damage assessment. This helps to reduce the potential for fratricide and increase interoperability in targeting. These weapons will be fully integrated into the new network, exchanging information between themselves and the nodes linked to the network itself. The result is a weapon that collaboratively interfaces with systems, potentially acts as an ISR platform en route to its target, adjusts its trajectory in-flight to optimize effort, and provides real-time impact assessment (when equipped with Electro-Optical/Infra-Red (EO/IR)).

Current technology allows NEWs to contribute to a network with 2-way communications. This means that the weapon is able to coordinate attack, coordinate sensor use, and provide ISR.

Strengths and Weaknesses of NEWs

Strengths

1. Acquisition of Fixed and Moving Targets at Long Ranges Using Existing Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR) Assets

ISTAR system data, imagery, and information are often crucial elements in the successful detection, identification, and engagement of opposing forces across the area of responsibility. Components of the network-enabled ISTAR system include sensor platforms (i.e. satellites, fixed and rotary wing, manned and unmanned aircraft, ground and sea-based sensors), their associated ground and exploitation workstations, as well as network-enabled remote workstations and Command and Control Information Systems (C2IS) that are not directly associated with an ISTAR system or sensor.[3] A weapon fully integrated in this network-enabled ISTAR system is able to acquire and engage fixed and moving targets at long ranges.

2. Operations in a Global Positioning System (GPS) Jammed Environment

Military uses of GPS include navigation and timing applications; therefore, interference in the GPS frequency bands makes them particularly vulnerable. Without a high-quality GPS signal, network-centric systems establish communication nodes linking NEWs with

the most accurate information available by the most timely and accurate source available without being limited to the delivery platform or GPS signal.[4]

3. Battle Damage Assessment (BDA)

Most of the time, initial BDA reports must rely on visual observation of the target and are usually based on a single source.[5] With weapons fully integrated into the network, the BDA is based on data provided through a combination of weapons system video, aircraft cockpit video, and varied visual and electronic reports from multiple other sensors, all in real time. This information will be relayed to the Joint Force Air Component (JFAC) to be incorporated in their overall assessment. It would not necessarily inform re-attack options, but an assumption of success, having confirmed a hit on the target as planned, would remain until follow on BDA reporting confirmed the outcome.

4. Advancements in Weaponry

Advancements in weaponry are not necessarily limited to being network enabled. Future weapons also fall into the bracket of hypersonic capabilities. While much of this is still under development, allied forces also have the ability to influence additional features of these weapons. Since modern day adversaries have layered and formidable defensive postures, it is reasonable to expect that stand-off weaponry is the foremost capability under development. Stand-off weaponry, developed to be sensor nodes by themselves with programmable loiter time for network-enabled programme changes as well as EO/IR capability for Positive Identification (PID) and BDA, will provide a significant advantage.

5. Shortening the Kill Chain

The advent of advanced weaponry forces us to revisit the targeting cycle's standing procedures to shorten the 'kill chain', i.e. to do it better or quicker. This will aid our commanders in defeating the enemy before they can react and counter our actions, thus enacting battlefield superiority, which is achieved by entering their OODA (Observe, Orient, Decide, Act) loop. The shortening of a procedure that currently works well and is already efficient may include, for example, delegation of engagement authority to lower levels or trusting sensors to ensure PID, CDE (Collateral Damage Estimation), as opposed to human visual acuity.

Weaknesses

1. Bandwidth and Net Design

Bandwidth is the primary driver of a network's speed. Unavailable or limited connectivity due to low or unstable bandwidth results in a slower exchange of information, thus failing to reach the required Information Superiority and impacting weapons' engagement. The closer the NEW is to the target area, the less available and reliable the bandwidth. Data prioritization is required to send only the essential data at the correct phase of the mission and reduce load on the network.

2. Ethics and Legal Aspects

The legal aspects of weapons employment is of paramount importance. They define the means by which we conduct ourselves and are accountable for our actions. It is not an argument whether a military force can kill people; it is legally doing so for military advantage that is proportional, distinctive, necessary and with regard for human life. Whenever we delegate responsibility, we must ensure that the legal aspects that define the way we operate are met. The delegation of PID to sensors is a perfect example, but if debated and accepted as meeting our principles, it will considerably shorten the ability to meet the approval criteria to strike the enemy.

3. Operational Procedures

Considering the multiple options that NEWs offer, the sharing or allocation of responsibility among stakeholders will have to be reviewed and updated, acknowledging all associated risks and consequences. Updated or new terminology will be required to be clear on how delegated engagement authority is disseminated for dynamic targets during post-launch execution. Joint Targeting is a process to engage the right target with the right weapon, but ammunition redirection requires a new framework for strategic decision-making.

4. Overlapping C2 and Effective Engagement Aspects

One clear aspect of modern weaponry is that it is under the ownership and control of specific groups. Whether it is a component weapon (e.g. ATACMS) or a national-owned weapon used within a coalition (e.g. TLAM), there is always the threat of loss of control over the assigned weapons. The disposition to forego weapon ownership, for the greater good of quickly striking the enemy with the best available asset, is a difficult threshold to overcome. Identifying where the weapon employment decision-making and control delegation sits will be key.

5. Methodology

A speeding up of the targeting process is not necessarily where the benefits would lie, as opposed to speeding up CDE approval, faster transmission of mission details, or delegation of engagement authority based on Situational Awareness. The Find, Fix, Track, Target, Engage, Assess (F2T2EA) targeting cycle should not be disrupted as such, as it is a proven set of repeatable processes to legally prosecute a target.

What will enable an enhanced methodology are connectivity developments, particularly regarding handover phases, authentication, and engagement authority

delegation. The reliability of intelligence and position, navigation, and timing data is essential to have consistent transition of responsibility and control.

6. Weapons Data

Releasability of weapons data that are covered by National Security Regulations may limit the inclusion of specific capabilities allocated to NATO within future modelling and simulation activities, exercises, research and development, etc. Sharing national sensitive information, e.g. weapon ranges for planning purposes, is challenging in the best of times. There will need to be an agreed means of working these issues within the coalition.

Future Targeting Cycles

Deliberate or dynamic, the targeting cycle can be very different and must be approached separately. The targeting cycle describes the deliberate means of allocating weapons to task for fixed structures that are planned through a cycle within the JFAC. This encompasses target development and authorizing of targets, with prioritization and execution to meet the commander's intent.

The same applies for dynamic targets, although they are mobile by nature and cannot be guaranteed to be struck through the normal cycle. The clearance of a dynamic target goes through a similar cycle to ensure all authorizations for legal, military, planning, etc. are met.

The challenge is how to improve both systems, without compromising procedures or legal obligations. An increased reliance on electronic means could shorten the time in clearing a target. Terrain mapping is not new, nor is the electronic capture of imagery. A visual clearance for all strikes, not necessarily for PID, but for CDE purposes is the norm. Should electronic means become acceptable to recognize change to imagery and clear a target for CDE purposes, then the potential to carry out a strike without waiting for visual confirmation could significantly shorten the time to strike. This would only be applicable to fixed targets.

Stand-off weaponry is becoming more common coupled with the problem of visual confirmation. Dynamic targeting is traditionally a rapid process to acquire a target and ensure it is legal, authorized, and tasked without compromising other priority tasking. Making it quicker is not necessarily better; however, with the development of NEWs, the ability to fire and forget from a stand-off position and then hand over programmed tasking of the weapon to another aircraft or ground unit is now under development. This will require a change in procedures for rapid planning to launch of a stand-off weapon and hand over the programming of the coordinates, enabling in place requirements to be more easily acted upon, e.g. a visual CDE clearance from a team with eyes on target, which afterwards conducts the appropriate programming. This would mean utilizing the best available weapon, from an increased arsenal, considering that many modern weapon systems would not be selected due to risk to aircraft or aircrews while establishing those visual confirmations.

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Vulnerabilities and Mitigations

The risk of vulnerabilities is extensive, especially considering the connectivity links needed by the NEWs. Sophisticated electronic attack and cyber warfare highlight NEWs' vulnerabilities associated with the increased system connectivity, from which 'stand-alone' weapons were essentially impervious.

Sensors/seekers could be susceptible to electronic attack, which could affect the weapon by feeding insufficient data and reducing effectiveness. Consequently, a network's vulnerability could lead to a complete loss of its services from jamming or from a lethal attack, data corruption from a cyber-attack, or increased latency which affects guidance, navigation, and control of weapons in flight.

It should be noted that every system has some weaknesses that can be exploited. Mission planning and logistical chain protection must be secured, so that NEWs vulnerabilities to cyber-attacks are mitigated from corrupted environments. Additionally, appropriate electronic protection measures are paramount to ensure maintenance of sensor and seeker data. Hardening of locations and protection of access points with encrypted software are potential protection solutions against electronic attacks, together with the creation of new algorithms and systems redundancies to counter attacks and protect them from latency.

Recommendations

- Robust joint investment in networked communications through partnerships with coalition members will ensure commonality and connectivity for future joint operations.

- The immediate challenge for a new C2 structure is a reliable, secure, and affordable communications system within a modern military construct. Investment in these areas will be paramount, especially for contested and forward deployed locations.

- Whilst mentioned only briefly, a new concept for C2 structures and target methodology implies a review of current Tactics, Techniques, and Procedures (TTPs), Standing Operating Procedures (SOPs) and doctrines to accept NEWs as normal.

- Establish a framework for strategic decision-making as part of the Joint Targeting process and, more specifically, on the delegation of authorities as part of the targeting cycle.

- NATO Defence Planning Process is invited to consider these issues in projecting future procurement, specifically with the integrated ISR technology on future NEWs.

Conclusion

Advancements in technology are a coming of age in modern warfare, where we are seeing a generational leap in connectivity, data management, and C2 challenges. The ability to master these challenges before our peers will define our future military advantages. This is a crossroads of major changes to modern warfighting when network enabling will become the new norm. As a coalition, there is a profound need to be on the same path of modernization where new partnerships in agile procurement and research in this field are a must.

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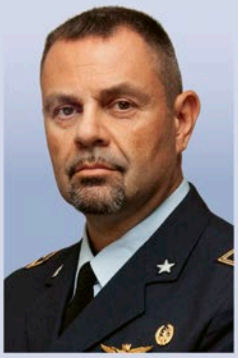
Lieutenant Colonel Francesco Esposito

joined the Italian Air Force in 1990. He was trained with the US Air Force SUNT programme at Randolph AFB, Texas, and in 1996 graduated as a Tornado Navigator/Weapon System Operator in Cottesmore, UK. As an aircrew with 156° Tornado Sqn and as an instructor with 102° Tornado OCU Sqn he participated in the flying operations in Bosnia and Kosovo. Between 2008 and 2012, he served as ATO Coordinator and Chief Strike cell in the Combined Air Operation Centre in Uedem, Germany, contributing also to the Operation Unified Protector in Libya. Currently, he serves as JAPCC Precision-Guided Munition Expert.



Mr Adam T. Jux

is a retired Royal Air Force Officer who also served in the Royal Australian Air Force and the Australian Army over his 27 years of military experience. He is a qualified targeteer and has worked in the discipline for the last 14 years, including on operations. He has instructed in targeting, collateral damage estimation and has mentored targeting at the Joint and Component levels. He has published a number of articles and contributed to white paper research regarding targeting in general and its interaction with intelligence and other disciplines. He is currently working as a civilian targeting consultant for NATO's Joint Warfare Centre in Stavanger, Norway under contract for CALIAN EUROPE AS.

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Human-Machine Interface: An Evolutionary Necessity

Developing Benchmarks for Future Driven Interface Designs

By Lieutenant Colonel Imre Baldy, HU AF, JAPCC

By Lieutenant Colonel Livio Rossetti, IT A, JAPCC

Introduction

Optimal pilot-aircraft interaction has always been considered a cornerstone for achieving effective operational performance while maintaining a high level of safety during a task or mission. As more and more complex flight tasks are carried out, more and more information reach the crew members. There are new technological solutions on the market, and the performance during a mission is measurable. When considering human-machine interaction based on advancements in neuroscience, it is possible to measure and evaluate the effectiveness of any Human-Machine Interface (HMI). To support aircrew's performance, the available innovations, such as data fusion or Artificial Intelligence (AI)-assisted decision-making and task management, must be leveraged for the successful conduct of military missions. AI and big

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data management are key factors when coupled with machine learning to improve and run modern operational scenarios. A network-centric, integrated weapon system provides flexibility to the Joint Force commander and contributes to the success of current and forthcoming joint missions.

In joint operations, when two or more nations use all available domains, it will be crucial to utilize all assets and capabilities as quickly and effectively as possible, in order to have the best overall picture of the battlespace. As such, it is important to address and validate the creation of the next generation of cockpits, optimized for the aircrew. Advanced command and control systems, which provide secure and interoperable support to conduct the mission, will ensure access to an integrated and synchronized system of systems and will enable information superiority on the battlefield. In the future, the way commanders at all levels visualize and understand the battlefield, utilizing certain aids to guide and direct their units, will be determinant for victory.

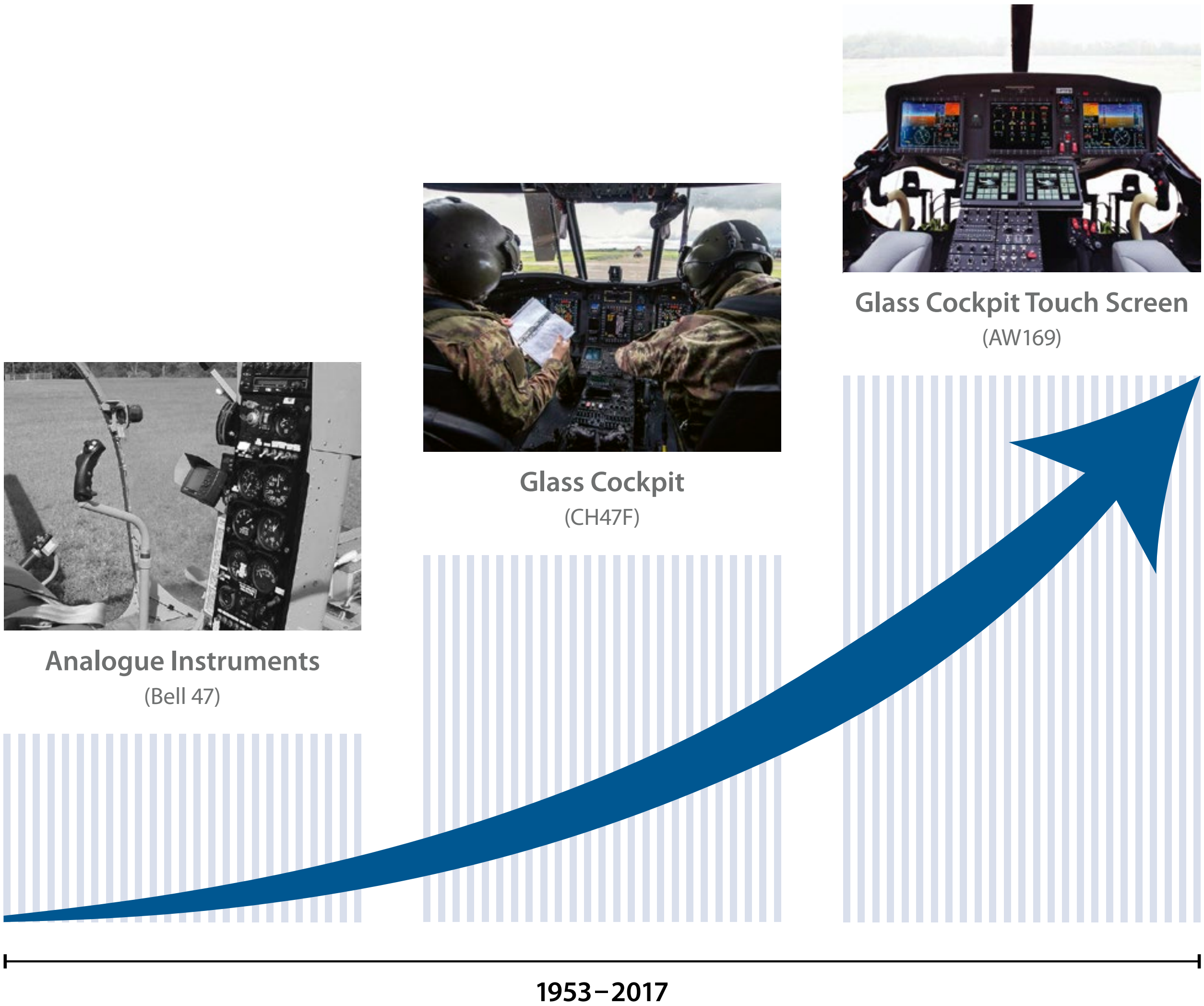
Operational Background

According to JAPCC's Joint All-Domain Operations flyer released in 2021, all-domain operations include 'the rapid processing of data and management of intelligence, as well as the technical ability and policies required to enable efficient operations inclusive of all contributed assets'.[1] Other NATO publications use the term Multi-Domain Operations (MDO), which primarily describes the same challenges of the mission environment. Finding a coherent, common-use term is evolving, but it will not change the meaning behind the definition of HMI. Additionally, it is important to develop a connected, sophisticated

interface that can assist commanders and their subordinate military personnel in sharing information simultaneously and without delay, as well as deciding and acting rapidly.

As Todd Prouty recognized in one of his articles 'Joint All-Domain Command and Control (JADC2) is taking shape as a guiding concept to link operations' and 'will use AI and machine learning to connect the joint force by collecting, processing and computing huge amounts of data at machine speed'.[2] As witnessed in this complicated scenario, the *tactical* and *flight* Situational Awareness (SA) of the flight crew is critical. Both types of SA are equally important as they might not only impact the successful completion of the mission, but even the strategic level's intent. The easiest way to define SA is as a thorough knowledge of your surroundings. *Tactical* SA implies that the crew knows the scenario, its task and role in the mission, and all troops involved in the same area of operations. They know how to fly the mission, and also the aim and consequences of success or failure. The *flight* SA mainly focuses on the flight's performance and parameters, the location in space and time, and the aircraft's performance. The two SAs are distinct and need to be monitored constantly during flight. Usually, both require different levels of attention in different phases of the mission and, where capacity exists, can be shared among crew members. Some technical enhancements can improve just one SA, but it is desirable to increase both simultaneously to meet requirements and raise the overall SA. These developments must also support the strategic level's intent and provide the SA it requires in the decision-making process.

Modern airframes and cockpits should support the on-board workload of the aircrew and combat pilots



HMI-Cockpit Evolution.

© Left to Right: Ramon Berk, Comando Aviazione dell'Esercito, Leonardo

require that support to remain effective. This could be managed automatically through AI, enabling the aircrew to focus more effort on their tasks and missions. It could be argued that it is a basic necessity for airframes to be enhanced with algorithms to complement the crew's ability to handle the increased information flow during flight.

During the conduct of operations it is anticipated that the situation may change rapidly and the commander must take immediate actions to re-task the forces. On the ground or in flight, the pilot may receive a new task on short notice. This new order should not be formatted as purely basic information; the support will be optimal when the whole update package can also be visualized. An example is a Digital Moving Map system depicting detailed information about friendly and adversary forces, including the coordination information. When the pilot changes the Flight Plan, the cockpit and all its settings will be updated automatically. As stated in the National Defense Magazine, 'the ability to assemble, fuse and analyze data from limitless sources, transforming it into actionable intelligence delivered to the tactical edge, requires unprecedented processing power on the move'.[3] To comply with these requirements, a push towards an integration of the next generation of HMI should be standardized in all modern cockpits.

Optimizing the HMI of Civilian Aircraft

Notably, recent technological developments of aircraft cockpits have seen tremendous transformations. In only a few years, the cockpit has transitioned from the 'classic flight deck', with analogue quadrants, to the modern 'glass cockpit' in which classical instruments are presented via sophisticated multifunctional displays. Most information is interlinked between the instruments, the Flight Management System, and the autopilot functions. In modern cockpits the traditional 'knobs and dials' have been abandoned and replaced by electronic reconfigurable displays and multifunction reconfigurable controls, the so-called 'soft keys'.[4]

Traditionally driven by safety and performance enhancements, developments in cockpit design and the way information is displayed seem much more driven by efficiency and competitiveness criteria.[5] For example, in the All Condition Operations and Innovative Cockpit Infrastructure (ALICIA) project, 41 partners from 14 countries are cooperating in research and development activities intended to realize a cockpit system capable of delivering all-conditions operations. Considering the increasing number of commercial flights in the near future, the project aims to achieve higher levels of efficiency and competitiveness by using new operational concepts and cockpit designs.[6]

ALICIA promises new solutions capable of providing the crew with greater SA while reducing crew workload and improving the overall aircraft safety. This is a radical rethinking of the HMI concept that seeks a holistic integration of technologies. In the envisaged concept, ALICIA makes use of multimodal input/output devices to deliver an all-conditions operations application integrated within an enhanced crew interface.[7]

Optimizing the HMI of Military Aircraft

Improving the HMI of military aircraft is a much more complicated task. The situations to be analysed are numerous and more complex when compared to commercial flights. In the military cockpit, the tasks associated with the flight itself merge with those necessary to accomplish the combat mission, often while flying in dangerous areas and degraded environments. Additionally, the military aircraft are equipped with many more devices designed to deal with the integrated combat mission and for armament system management.

The typical tasks for military flights can be split in two categories:

- Piloting and navigation: performed during the whole flight;
- Combat tasks: only performed during some phases of the flight mission.[8]

When combat tasks occur they must be carried out simultaneously with piloting and navigation tasks, which is the main difference between military and commercial aviation. Based on own experience, the military pilots have to judge which one has the priority at any particular phase of flight. Therefore, they devote most of their resources to it, leaving what are often mistakenly considered less important tasks to be performed by on-board automatic systems or using the remnants of their attention.

Unfortunately, the complexity and unpredictability of military flights, in terms of tasks, risks, threats, duration, weather conditions, etc., often cause the crew to easily exceed their personal limits. When it happens, the risk is that the mission will not be accomplished or may even be abandoned. In the worst case scenario, the aircraft and crew could be lost or the crew could act without proper or optimal SA, leading to an increased risk of collateral damage.

Emerging and disruptive technologies can improve the HMI on future military aircraft. They can introduce new solutions based on AI, deep learning, or Real-Time Convolutional Neural Networks (RT/CNN) to integrate new capabilities, such as systems with cognitive solutions. As an example, the development and evolution of Cognitive Human-Machine Interfaces and Interactions (CHMI2), used to support adaptive automation in the One-To-Many (OTM) concept for multiple Unmanned Aerial Vehicles,[9] could also be exploited to support adaptive automation in the accomplishment of *'multiple tasks in the military cockpit'.*

Similarly, it may be possible to investigate and develop CHMI2 to monitor the pilots' cognitive workload and provide appropriate automation to support overloaded crews. These advanced systems should be able to read the orders arriving in the cockpit, analyse the related threats, and propose the most 'suitable to task' mission profiles and concepts of operation. At the same time, they should compute all mission required data, such as fuel consumption, time on target, 'playtime', routes, battle positions, disposition of enemy and friendly forces, selection of weapon systems and ammunitions, collateral damage estimates, and the appropriate rules of engagement, etc. The level of automation and HMI formats and functions will then be dynamically chosen considering the crew's cognitive state.

In one of his studies from 2009, Cezary J. Szczepanski proposed a different approach to HMI optimization based on the fact that the critical factor for mission success is the workload of the aircraft operator. If the workload exceeds a specific limit, the mission cannot be successfully completed. Therefore, he proposed a way to objectively measure the crew's workload during mission execution; specifically, the design of an HMI in such a way to ensure, even in the worst case scenario, that the workload could not exceed the limits of the human operator.[10]

Almost eleven years later, in 2020, the NATO Science and Technology Organization set up a research group to evaluate whether aircrew have the capability to perform their assigned tasks, with enough spare capacity to take on additional tasks, and further capacity to cope with emergencies. This group aims to identify and establish a real-time objective methodology, based on specific metrics, to evaluate HMI effectiveness.

The assessment of the cognitive state through real-time measurement of neurophysiological parameters promises to support the development of new forms of adaptive automation. This will implement an enhanced level of autonomy, similar to a virtual on-board pilot, which will assist crews in decision-making and relieve them of repetitive or mission-distracting tasks. Adaptive automation appears to be a crucial component in achieving optimal HMI. It promises to support high levels of autonomy to reduce human workload while maintaining sufficient levels of systems' control. This may be particularly important when performing missions that require a sustained workload. This presupposes a comprehensive analysis of the ethical and moral implications associated with an autonomous decision-making machine. However, this is beyond the scope of this article.

Recommendations

The battles of the future will be increasingly fast-paced and dynamic. Emerging and disruptive technologies promise to revolutionize the way commanders at all levels will plan and conduct battlefield operations. AI, machine learning, enhanced command and control systems, and advanced big data management will significantly benefit commanders, improve SA, and dramatically accelerate the decision-making process. Modern militaries envisage future operations in a fully integrated, connected, and synchronized way, which spawned the MDO concept to refine commander's ability to task/re-task all forces quickly and effectively across multiple domains.

This pronounced dynamism in the conceptual and planning phases must be reflected in the execution phase as well. Therefore, it must be assumed that while commanders will be able to reorganize and re-task forces with little or no prior notice, crews must also be able to process and execute those new orders quickly, effectively, and safely with little or no time to pre-plan or rehearse.

These new requirements will undoubtedly influence the design and development of the next generation of cockpits for military aircraft. There is a need to adopt a new way of conceiving the next generation of HMI that focuses more on the pilot's true cognitive capabilities. Additionally, new solutions are needed to providing the crew with greater SA, while reducing their workload to the maximum acceptable level that they remain effective. They should incorporate task prioritization principles by judiciously considering what the aircrew can hand over to autonomous processes or systems.

This article has focused on air power and the pilot's workload while on-board the aircraft. It is foreseen that in modern scenarios all platforms will face the same challenges. At every level of an operation, all military personnel should develop a new mindset that reflects the increased integration and usage of HMI. For this to happen, a renewed awareness of the importance of human factors is needed. Similar to civil aviation, NATO will need to develop and adopt new criteria to guide the design of tomorrow's military aviation interfaces. HMI improvement must encompass all aviation tasks and focus on enabling real-time planning and execution. Without careful attention to the pressures military pilots are exposed to, HMI improvements will only make piloting safer without a similar increase in effectiveness during mission execution. Developing the means to assess the crew's cognitive state through real-time measurement of neurophysiological parameters and the subsequent development of new forms of adaptive automation will be critical to achieving an HMI that meets the requirements posed by future battlefields.

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Lieutenant Colonel Imre Baldy

joined the Hungarian Defence Forces in 1988 and started his military education at 'Szolnok' Military Aviation College in Hungary. He received his first rank of 2nd Lieutenant as weapon operator/co-pilot in 1992. In 1997, he received his first appointment at the higher staff level when he joined the Hungarian Air Force Staff in Veszprém, where he gained experience in international relations and air force defence planning. In 2007, he moved to Székesfehérvár where the new Hungarian Joint Force Command was established. Among other responsibilities related to helicopter business, he was also tasked with air force short term planning. He has flown Mi24, Mi-8, and AS-350 helicopters. Starting July 2018 he became the JAPCC's SME in Manned Air/Attack Helicopters.

Lieutenant Colonel Livio Rossetti

was commissioned in the Italian Army in 1993, as an infantry officer. After three years he transited to the Army Aviation schools and graduated as a rotary-wing pilot in 1998. He has served as Platoon Commander, Squadron Commander, and S3-cell Chief. He has flown utility helicopters: AB-206, AB-205, AB-212, AB-412, as well as, the AW-129 Mangusta combat helicopter. He has been deployed to the Balkans Peninsula (Albania, Kosovo), Middle East (Lebanon, Iraq), and Central Asia (Afghanistan) several times as an aircrew member or a staff officer. He is also a qualified CBRN (Chemical, Biological, Radiological and Nuclear) specialist, an airmobile instructor, and he is currently stationed at the JAPCC as the Air-Land Operations SME in the Combat Air Branch.

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Introduction

Today's military operations are becoming more complicated with the increasing number and variety of options available to commanders at all levels. The expansion of military activity beyond the Air, Maritime, and Land domains to Space and Cyberspace has broadened the community of warfighters that modern militaries require to operate successfully and efficiently in the battlespace. As the changing character of war becomes entangled in the digital world, future conflicts will be decided by those who are the fastest at collecting, correlating, fusing, analysing, and securely transporting the required quality data across multiple domains to the appropriate decision-maker.[1] This inevitable transition into a new technological era directly affects all critical air operation concepts, including Close Air Support (CAS).

In military tactics, CAS is defined as air action, such as air strikes, by fixed- or rotary-wing aircraft against hostile targets in proximity to friendly forces and has

Close Air Support Command and Control

Digitally Enhanced CAS Operations

By Lieutenant Colonel Osman Aksu, TU AF, JAPCC

played a critical role in recent military operations. Providing CAS to joint forces remains a crucial mission in the context of joint operations. In addition, CAS has to meet operational requirements to maintain its undeniable place in future wars. One of the basic criteria to achieve this is to act seamlessly with other forces while effectively and efficiently conducting all CAS missions.

Since CAS requires detailed coordination between forces to maintain high-situational awareness on the battlefield, having the ability to operate in all domains with improved and digitized communication systems, which complement traditional CAS procedures, is vital for conducting effective CAS. One way to attain this goal is the enhanced Digitally Aided Close Air Support (DACAS) capability.

DACAS is defined as a machine-to-machine exchange of the required CAS mission data between the Joint Terminal Attack Controller (JTAC), or the Forward Air Controller (FAC), and a CAS platform or a Command and Control (C2) node.[2, 3] The primary purposes of the

DACAS capability are to identify friendly forces, locate enemy positions, reduce human input error, share real-time targeting information between CAS participants, and supplement voice communication. A few nations are currently using datalink standards with multiple network options and message formats to provide evolving DACAS capabilities. However, there are critical interoperability problems with this methodology, due to the diversity of the national communications capabilities and systems as they are often unable to communicate seamlessly with each other. Recent DACAS activities, notably in the Bold Quest events,[4] have focused on developing and improving the interconnectivity or the machine-to-machine interface. Collaborative efforts are developing gradually, with some technical aspects concentrated on incorporating emerging and cutting-edge digital technologies as we move towards a more effective CAS.

Digitally Capable Communications in CAS Operations

C2 tasks traditionally include establishing the command hierarchy, authority allocation and delegation, planning, allocating resources, and assigning and managing functions accordingly to the mission's objectives. Much of the available data is often irrelevant to most users, and there must be guidelines on who gets what information. In the future, information technology must enable decision-makers access to high-quality relevant information, at the right moment, corresponding to their position within the C2 organization. C2 is not just about situational awareness; it is also about how and who makes decisions. Dynamic, real-time information sharing and networking are critical for establishing full operational capabilities and facilitating these exchanges.[5] Most NATO member nations' services operate dedicated, yet independent C2 systems. Often, these systems do not communicate seamlessly with each other. Sometimes, even the different branches of a nation's military use C2 systems tailored to their specific needs and special conditions. However, many NATO nations have identified this issue and are in the process of developing modern, overarching networks, aimed at bringing the different services under a unified C2 architecture.[6] Effecting new C2 among allies will require commanders and subordinate commands to operationally and technically digest the cross-cutting nature of Multi-Domain Operations (MDO). NATO is already acting on this challenge, thus preparing for future interoperability problems.[7]

Effective C2 is also one of the critical factors in leading successful CAS missions and minimizing the likelihood of fratricide. CAS C2 requires a secure, dependable, and interoperable communications system between aircrews, air control agencies, JTACs/FACs, ground forces, and fire support agencies. From a CAS standpoint, sensor and communications suites represent the system's heart and soul. Generally, communication capabilities should be reliable and interoperable enough to move the CAS asset to the target area safely and execute the mission effectively.

Aircraft and ground units have a variety of communications equipment, which operate across a range of frequencies, enabling voice or digital communications during a CAS mission. For instance, JTACs are equipped with various radios to communicate with aircrews via voice and with specific devices to enable digital data communications for DACAS. However, aircraft capabilities vary, affecting the contact with the JTACs, and not all aircraft are capable of digitally communicating across most common digital systems and message formats.[8] Conveying the wrong message, due to miscommunication, especially during the targeting phase, can cause unexpected collateral damage. Therefore, identifying friendly forces' locations and accurately marking targets' positions directly enhance the situational awareness of a CAS team. All CAS participants rely on accurate battlefield information provided by all available assets during every part of a CAS mission.

The transition to digital control of CAS operations began in earnest over the past decade. With little guidance to ensure interoperability, nations often fielded non-standard, non-interoperable, service-specific digital data exchange capabilities. These non-interoperable systems degraded mission performance in joint and coalition environments and increased the potential for human errors. Some NATO and national capability events and exercises assessed the Alliance's

digital CAS interoperability issues. While the development of tablet digital communications has been underway for some time, the current focus is to develop an improved data load file that provides optimized digital, machine-to-machine communication between JTAC and striker. Overcoming these interoperability issues will improve the speed of the CAS information exchange and data accuracy, enabling CAS forces to be more effective and resilient.

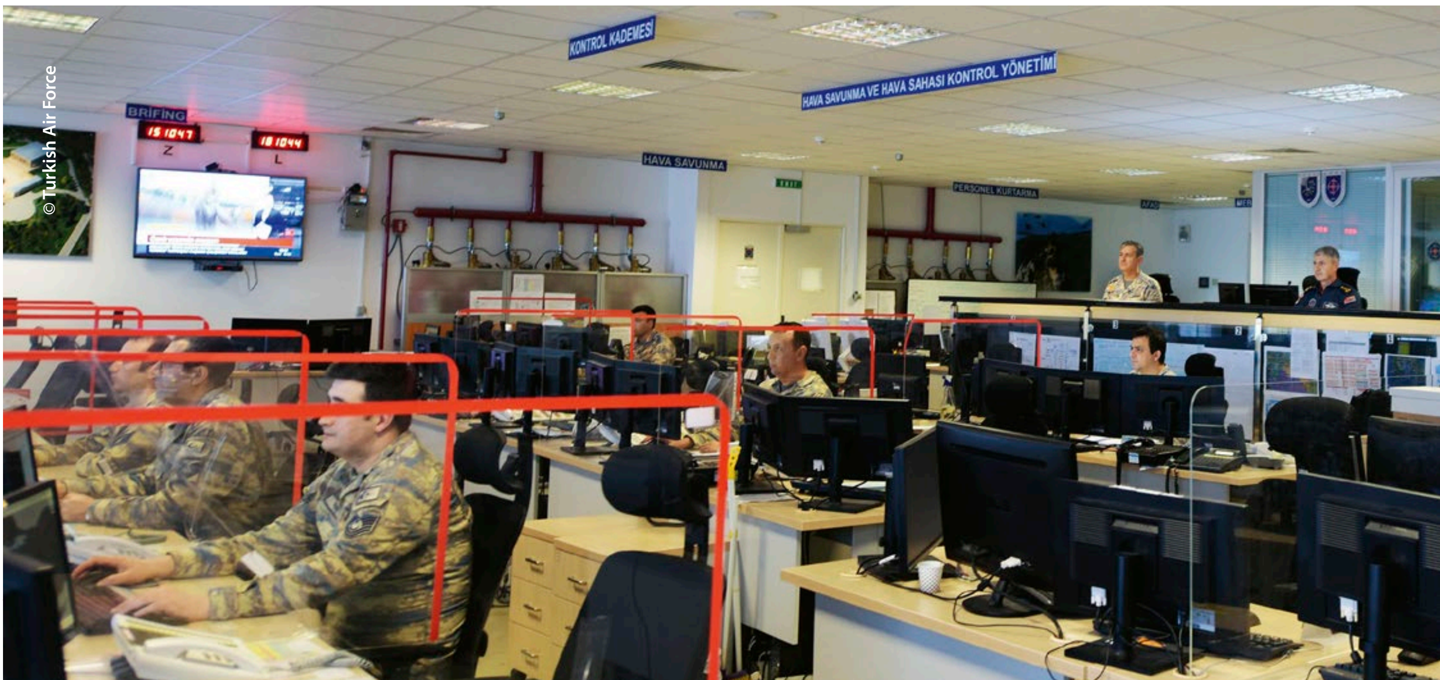
NATO Communication and Information Agency has worked to develop an understanding of the standards required for DACAS equipment and identify interoperability challenges. The Bold Quest exercise series aims to develop CAS C2 and DACAS capabilities at all levels, offer new solutions to address interoperability problems, and use them synchronously between the participating countries.

However, there has been much delay in accepting digital technologies, which has led DACAS development efforts to be coordinated across services and nations. Standardization has not occurred across all Alliance's JTAC schools, partly due to the large number of disparate national and service-specific communications networks used for CAS.[9]

A Battle-Proven Approach

A system's survivability is defined as 'the capability of a system to avoid or withstand hostile environments.'[10] From the commander's point of view, taking all necessary steps, starting from the research and development stages of new equipment, is essential for providing safety for the troops on the battlefield. Generally, the technological advances implemented into extant or new weapons and sensor systems, besides influencing C2 structures, drive the amendment of concepts, doctrine, and tactics, techniques, and procedures. There must be a balance between combat survivability, mission performance, and systems' reliability. The responsiveness of Air Power is crucial for ground forces' survivability, with a direct impact on their schemes of manoeuvre.

The Turkish Air Force (TURAF) has made one noticeable combat survivability approach for CAS operations. Turkey has conducted successful air and ground operations against terrorist organizations for a long time, especially in high-threat and contested environments such as Syria. Syrian urban environments create complex challenges when conducting CAS. Apart from the risks posed by the defensive strategic weapon systems at high- and mid-altitudes, the lower echelons of the Syrian airspace were also dangerous. Peer-adversary jamming activities also challenged the friendly communications networks during these air operations. To overcome the significant environmental challenges, minimize the threat exposure, and respond immediately to time-sensitive and fleeting targets, TURAF established a digital backbone to



expedite the application of CAS. During the CAS execution phase, digital aids to verbal communications such as machine-to-machine tasking and information exchange among CAS participants provided advantages of speed and accuracy.

The main goal was to provide appropriate means to maximize mission effectiveness and combat survivability of both CAS assets and friendly ground forces in this high-threat operational environment.

The Turkish Joint Force Air Component (JFAC) is the central and final control node for tactical air command, control, and communications and remains the focal point for coordinating aerial firepower in CAS missions. The JFAC embedded CAS team provided air expertise and has integrated the liaison and coordination functions together with other supported ground forces. Having a resilient digital and secure communications network interconnecting all services plays a crucial role in air operations. JFAC digital solutions supported missions across all communications infrastructures (wireless access, telephone access, intercom, telephone conference loops, and Link-16 voice loops). With the help of those capabilities, the JFAC carried out efficient air mission control with traditional elements (coordination of artillery fire, airspace control measures, safe routing of CAS aircraft, and distribution of C2 messages among all participants), expedited communications, and enhanced cognitive awareness on the battlefield. Decision-makers executed collective actions while being responsive to the changing environment. Timely target acquisition was fundamental to effective and responsive CAS. Therefore, all available Unmanned Aircraft Systems (UAS) sensor capabilities, used for target acquisition to pinpoint enemy locations and discriminate them from friendly troops and civilians, were fused into the joint operation centre to feed the JFAC's dynamic targeting processes in real time. With this support, the CAS team and planners could obtain timely and accurate intelligence data on the enemy's capabilities and locations, in order to make informed decisions.

TURAF deployed agile software capabilities to cover all necessary data, such as Air Tasking Orders (ATO), Airspace Control Orders (ACO), Airspace Control Plans (ACP), and Notice to Air Missions (NOTAM) etc., in a digitized information network pool. All C2 elements reached out to the Single Integrated Air Picture (SIAP) over the network, which was a crucial decision-making element for airspace management. It produced synergy, efficient information transfer, and accurate data exchange among services. The necessary warfighting data was fed into all other services or shared on request. Creating more C2 nodes on a case-by-case basis and handing over more responsibilities to subordinate units via mission-type orders helped achieve the commander's intent.

Through this overarching CAS C2 construct, the joint force's capabilities were enhanced beyond the limits of individual sensors leading to better coordination of engagements, superior management of scarce battlefield resources, and greater situational awareness over larger areas.

Going Forward

Effective CAS requires detailed coordination between aircrews and ground forces, coupled with two-way seamless communications capabilities. Technology is rapidly maturing and becoming a vital factor in future combat operations. By leveraging the capability of digital data communications systems and voice communications, coordination is enhanced to achieve accurate, timely, and responsive CAS operations. However, there are always interoperability challenges hindering these efforts. To improve the interoperability in NATO regarding DACAS, a thorough understanding of the specific digital communications capabilities is required.

Likewise, by constantly addressing the interoperability issues and emphasizing the need to share relevant information, future situational awareness will be set, especially in the light of technological developments and lessons learned. The ability to speak the same digital language with each other in joint operations will contribute to the effectiveness of NATO forces in contested operational environments. The standard one-size-fits-all solution is not always available, and decision-makers should explicitly balance and leverage emerging technologies according to military requirements to maintain the edge in future high-threat battle arenas. Other than the technological mitigations for challenging C2, the next best option might be to digest the lessons learned from past air campaigns in geopolitically sensitive and risky areas. Creating cognitive awareness among the Alliance's member nations will be crucial to enhancing the situational awareness of DACAS and CAS capabilities in future conflicts. To win future battles, the side with an information advantage across multiple domains will undoubtedly be more successful. It is essential to ensure that the right information is available to the right decision-maker at the right place and time. More than ever before, Air Power practitioners must have a clear and common understanding of simultaneous manoeuvres in multiple domains. Through NATO's Defence Planning Process, the Alliance should harmonize new concepts with new thinking to adapt MDO to interoperability and preparedness for C2 resilience.

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Lieutenant Colonel Osman Aksu

graduated in 2001 from the TURAF Academy with an Electronics Engineering Degree. After undertaking flight training and basic Weapons Controller training in İzmir, until 2003, was assigned as Weapons Controller at Diyarbakır CRC. In 2008, he was selected as AEWC Project Officer for Peace Eagle in the US. He returned to TURAF HQ Ops Division in 2010 and worked as PE Project Officer until 2013. Same year he was selected as Weapons Controller at NAEW FC GK and, in 2014, Fighter Allocator at CRC Ankara. Between 2014 and 2019, while assigned as Airspace Coordination Officer in ATC Ankara, participated in Airspace Control-Management activities for US/Coalition OIR missions. In November 2019, he became the CAS/JTAC SME in the Combat Air Branch of the JAPCC.

The Role of Aircraft Carriers in a Contested Age

Retaining Primacy in the Maritime Domain

By Commander Andrea Magi, IT N, JAPCC

Introduction

As the Maritime domain is becoming an increasingly complex and contested environment, questions are raised as to how future operations at sea will be conducted and what capabilities will be needed. In this regard, the role of the aircraft carrier has long been debated, as the advancement of weapons systems and other disruptive technologies may hamper its ability to provide Sea Control, Power Projection, and Freedom of Navigation.

Understanding the challenges that navies – and in particular aircraft carriers – will face in the contested global and maritime environments helps identify future roles of these formidable assets, both as extraordinary political instruments and effective military tools.

The Maritime Domain – A Contested Environment

Following the end of the Cold War, western nations may have considered the Maritime domain as an uncontested environment to conduct Sea Control and Power Projection operations in blue and littoral waters unabated. Additionally, with no strategic competitors, NATO and western navies diverted their naval industries towards enhancing their amphibious and maritime security capabilities to counter illegal activities at sea and ensure the Freedom of Navigation.[1]

Nevertheless, in the 21st century oceans and seas have become the principal arena for strategic competition and naval rivalry, with the resurgence of Russia and the rise of China as global economic and military powers.

Historically, Russia has always placed a particular focus on the Maritime domain. The current Russian naval policy considers the Russian Federation Navy (RFN) one of its most effective instruments of strategic deterrence, either nuclear or non-nuclear.

Currently, the Russian shipbuilding industry seems unprepared to achieve the strategic goal of a complete modernization of the navy.[2] Nevertheless, a new

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fleet of technologically advanced submarines and smaller surface vessels, both equipped with the formidable Kalibr advanced missile system, flanks the legacy Soviet-era units as a testament to the renewed, aggressive posture of Russia's maritime policy. RFN training and exercises at sea have significantly increased in quality and quantity. Although the number of larger ships has not increased recently, their deployments at sea and 'show-the-flag' activities have increased considerably in the last decade. The constant presence of military units in the Mediterranean, the recent combined activity with Chinese units in the Sea of Japan, and the exercises conducted in the Baltic and North seas in the last years demonstrate Russia's return to the world's scene of naval competition and its power projection capability.[3]

Regarding China's ambitions in the Maritime domain, Yin Zhongqing, National People Congress Financial and Economic Committee vice-chairman, stated that 'the ocean, deep sea, and polar regions could be developed and exploited' and that 'strategically managing the ocean has become the necessary path for China to open up and develop new space, give birth to new economic industries, create new engines for growth, and build new shelters for sustainable development in the new period and a new era'.[4]

To this end, the People's Liberation Army Navy (PLAN) has developed the largest naval force on Earth, with 355 ships and submarines of which an estimated 145 are major surface combatants. China is building aircraft carriers and related fighter jets, modern surface vessels, a new generation of submarines, amphibious assault ships, and a fleet of icebreakers. This number is expected to grow to a predicted total of 460 ships by 2030.[5]

It may be assumed that, if uncontested, the PLAN will be increasingly capable of achieving sea control throughout the seven seas by 2030 and potentially sea superiority by 2049.[6]

Aircraft Carriers in the Contested Maritime Environment

The traditional advantages of aircraft carriers are impressive: global reach, long-endurance, massive firepower, rapid deployment and re-deployment, and multi-tasking.

Furthermore, the intrinsic value of an aircraft carrier must also be considered from a political and diplomatic standpoint. In times of global aggressive competition, such a powerful asset provides a nation with a tangible and prestigious effect through presence alone. The media impact of its presence in a given area, far from the motherland, and its port visits to both friendly and potentially non-friendly countries magnifies a nation's global reach and amplifies its power. Aircraft carriers are 'key forward-based elements of the nation's deterrent and warfighting force'[7] and 'the most capable offshore military warship mankind has ever built and a symbol of the absolute navy and national strength'.[8] From this perspective, the value and relevance of aircraft carriers in uncontested or reduced-threat areas is undeniable.

Nevertheless, in highly contested environments, the reputation of grandeur that has characterized the aircraft carrier since the end of the Cold War would be strongly questioned. Soon, aircraft carriers will have to choose between operating where they can be effective and where they can prevail. In particular, it is conceivable that adversaries' Anti-Access/Area Denial (A2/AD) capabilities may prevent entry of a Carrier Strike Group (CSG), forcing it to operate beyond its preferred range, thus 'denying or degrading its ability to support other military operations'.[9]

Major topics of discussion among naval theorists revolve around the future roles of the aircraft carrier or, rather, which of the traditional roles are still viable in the light of the changing operational environment and what capabilities are required to compete with the adversaries' A2/AD.

Rubel R. C., a distinguished military professor at the United States (US) Naval Academy, identified six historical roles for aircraft carriers: eyes of the fleet, cavalry, capital ship, nuclear strike platform, airfield at sea, and geopolitical chess piece.[10] Based on historical hit-and-run land strikes, the role of cavalry has largely been replaced by the employment of naval cruise missiles, avoiding the need for aircraft carriers to enter danger zones to perform air missions. Nuclear strikes also pertain to the past, being substantially inherited by land- or submarine-borne ballistic missiles or by long-range bombers.

Consequently, the critical issue of a future role concerns the remaining four missions, which are strongly related to the CSG defence capability and its embarked air wing. The CSG impunity at sea relies on a multi-layered structure, including aircraft and medium- and long-range surface-to-air missiles to counter inbound enemy targets at long distances and point defence systems for short-range engagements. However, due to adversaries advanced A2/AD systems, in the future this three-layer defence system may 'best be thought of as a strainer, not a shield'.[11] Therefore, it has been observed 'that carriers themselves may not be able to move close enough to targets to operate effectively or survive in an era of satellite imagery and long-range precision strike missiles'. It is a common assertion that uncrewed assets, complementing the crewed ones, will most probably solve this limitation. The latter are admittedly necessary for those missions that require a level of human judgment. In addition, 'the manned aircraft simply is too useful, too adaptable and flexible, to be abandoned' and their role will remain pivotal in

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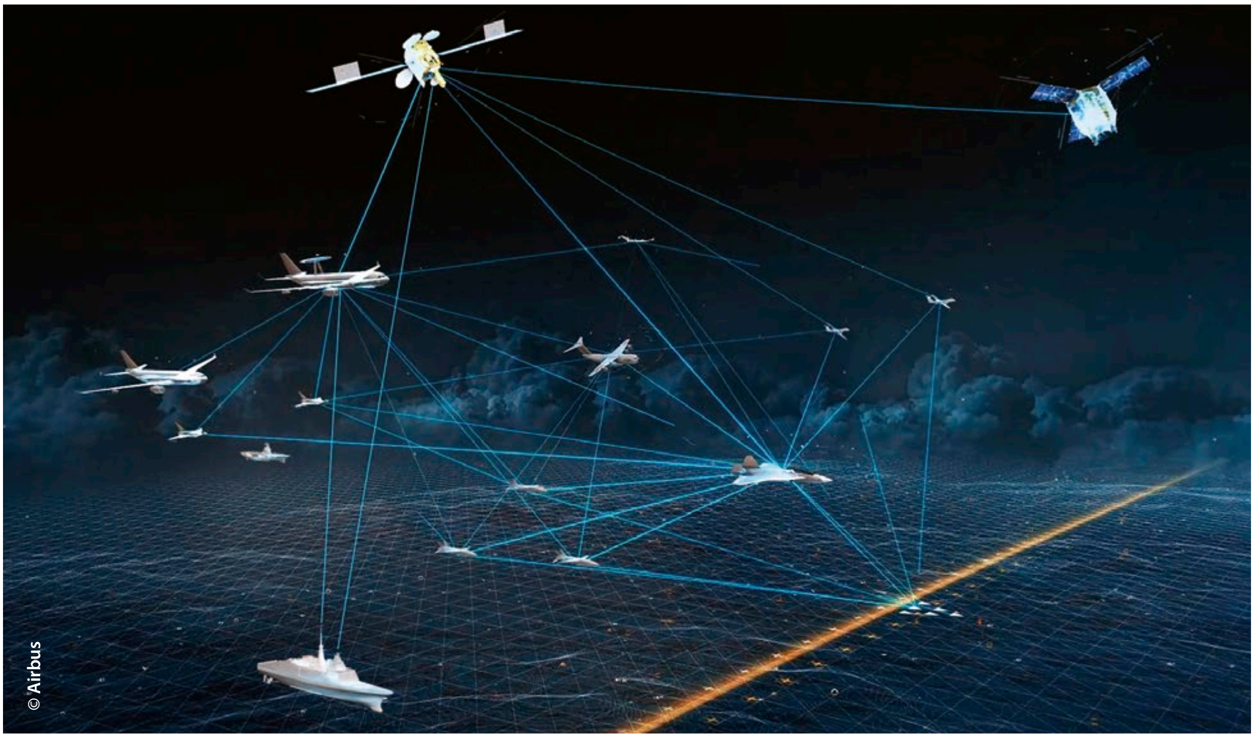
low-intensity operations, such as counter-insurgency, counter-terrorism, or maritime security.[12]

However, to mitigate the risk of aircraft carrier losses in highly contested A2/AD environments, it will most probably be necessary to embark on large numbers of Uncrewed Combat Air Systems (UCAS), loaded with a diversity of weapons and sensors and able to fulfil multiple missions. Such an option may be the best solution to guarantee the aircraft carrier's offensive firepower at greater distances and increase its survivability. The United States Navy, for instance, has been testing the X-47B UCAS, an uncrewed carrier-based, long-range strike fighter capable of autonomous aerial refuelling. The system was intended to exploit 'the full potential of what unmanned surveillance, strike, and reconnaissance systems can do in support of the Navy' and the possibility of operating seamlessly with crewed aircraft as part of a Carrier Air Wing.[13] Eventually, the programme was cancelled in favour of the less stealthy MQ-25 Stingray, an uncrewed autonomous aerial refueller that will extend the combat radius of embarked fighters.[14] Nevertheless, the US is revisiting the requirements for an uncrewed long-range striker, particularly after China has recently introduced a stealthy attack drone, the Gongi-11.[15]

One of the main issues related to uncrewed systems is the level of autonomy, namely the ability to interpret a specific tactical situation and react accordingly. The development of Artificial Intelligence (AI) and Machine Learning (ML) is not yet sufficiently mature enough to resolve the ethical and legal issues to allow a machine to take decisions in ambiguous situations. Given the current technological shortfalls, it is generally recognized that 'until research is mature enough to coherently implement AI in a broad range of scenarios that military forces may encounter, unmanned systems will continue to be used only under close human supervision'.[16]

Consequently, the necessity for the CSG to organically Command and Control (C2) crewed and uncrewed aircraft poses another set of requirements.



These include robust connectivity and the ability to process vast amounts of data to gain information superiority and outpace the adversary's kill chain. These requirements fall within the broader concept of Multi-Domain Operations (MDO).

MDO represents 'a response to a changing competition-space characterized by complex problems that defy current approaches and A2/AD challenges which require more fluidly integrated capabilities across all domains'.[17] It focuses on integrating and synergizing capabilities from the maritime, air, land, space, and cyber domains (to include the electromagnetic spectrum and information environment) to expedite the planning and execution processes by analysing large amounts of information at high speed and by connecting sensors to shooters. Future military operations will require the integration of different battle networks in a system of systems to increase the overall operational tempo.

As the maritime environment may well be considered a joint theatre, rather than the natural environment for navies to operate in, current and future scenarios require greater cooperation and interoperability across all domains. Domains' mutual support will increase the maritime warfighting ability, including the air power. The proliferation of multinational projects, such as the F-35, may enhance prospects towards interoperability.

However, the path to fully integrated domains and capabilities is not free from pitfalls. The current C2 construct is not robust enough to manage the widespread and continuous multi-domain integration at the pace and reliability required for future operations. In addition, the coexistence of legacy and next-generation systems suggests integration and interoperability issues that need resolution. Above all, operations will require synergy between services, jointness across multiple domains, and improved interoperability between nations and the Alliance.

The need for NATO to operate synergistically across all domains is paramount. Understanding how the CSG will fit in future multi-domain operations will allow it 'to survive against a peer adversary, and remain a viable, valuable asset in the Joint Force Commander's portfolio'.[18]

Conclusions

The Maritime domain will undoubtedly be a principal stage for strategic competition in the future. Advanced weapons systems – and the proliferation of disruptive technologies by state and non-state actors – have increased the risks to freedom of navigation and global trade and pose a severe challenge for maritime security in the open seas and littoral regions. Furthermore, the development of a more aggressive naval policy by NATO's strategic competitors requires an effective naval instrument capable of guaranteeing Sea Control in areas of strategic interest.

Among all military instruments of naval power, the aircraft carrier and its embarked aircraft have been pivotal for decades. While the political and diplomatic roles of the aircraft carrier remain unchanged in a contested, yet peaceful environment, current threat systems have undermined its perception of invulnerability. This may require an adaptation of their traditional roles and missions. Moreover, the proliferation of anti-access systems emphasizes the need for innovative concepts – such as MDO – to maintain superiority at sea. By exploiting full integration, interoperability, and synchronization across all domains, NATO navies can increase the effectiveness of crewed and uncrewed aerial systems and operate with greater lethality from safer distances.

There is no doubt that nations and their navies will continue to value the political, military, and economic power associated with aircraft carriers. Nevertheless, work remains to ensure their viability against current and future high-end threats.

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Commander Andrea Magi

joined the Italian Navy in 1990. After serving on board frigates and the ITS Garibaldi as the Electronic Warfare Officer, he was assigned to the Gruppo Aerei Imbarcati, the Italian Navy Harrier AV8B+ Squadron, as Intelligence Officer and served on board Italian Navy aircraft carriers. In 2014, he was appointed Fleet Air Arm Intelligence Branch Chief. He participated in all major operations including 'Sharp Guard', 'IFOR', 'Enduring Freedom', 'ISAF', 'Leonte', 'Unified Protector' and 'Sophia'. In September 2017 he was posted at the European Personnel Recovery Centre, in Poggio Renatico (Italy), as Education Staff Officer and JPR Instructor. Currently he is assigned at the JAPCC, Combat Air Branch, as Maritime Air Operations including Carrier Operations (RW) SME.

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Cluster Satellite Architectures

Micro Satellites Formation Flight

By Lieutenant Colonel Tuncay Yunus Erkec, PhD, TU AF, National Defence University

Introduction

Satellites make outstanding contributions to the military, political, and economic power of states, especially in surveillance, reconnaissance, offensive, and defence missions.[1] In addition, the extensive coverage and broad-spectrum capabilities of satellites are also valuable for the civilian sector for human migration monitoring, meteorology, forestry, and agriculture.[2] Besides their low-cost development and zero risk to human life, satellites also have the advantage of providing photogrammetry services beyond the capabilities of manned aircraft.

Today, as technology advances at an ever-increasing rate, miniaturization brings forward the possibility of using smaller satellites and, consequently, reducing space missions' launch, engineering, and construction costs.

When examining the use of a single large satellite versus a cluster of smaller satellites, in terms of cost-effectiveness in performing complex space missions, it is worth considering the set-up cost. Set-up costs are one of the biggest portions of the overall cost of satellite development and considering the required number of ground stations and installations it is more economically viable to perform a mission with a large satellite. A small-satellite cluster will become increasingly economical after the initial set-up, considering the multitude of uninterrupted missions that can be conducted with space and ground systems backing each other up.

Whether micro, nano, or pico, small satellites have unique properties such as relative lightweight, low cost, and rapid production. For these reasons, small satellites are gaining widespread reach and are constantly fielding new capabilities. They are used for various purposes, such as communication or remote sensing;[3] however, due to their constraining features, e.g. limited mass, volume, power, and payload, some space missions have to be carried out using constellation formations rather than a single satellite.

In general, the lifespan of the cluster's satellites, which are designed without a propulsion system, varies according to the orbital parameters. The service life of a satellite cluster operating at 400 km in Low Earth Orbit (LEO), under the effects of outer-orbital perturbations

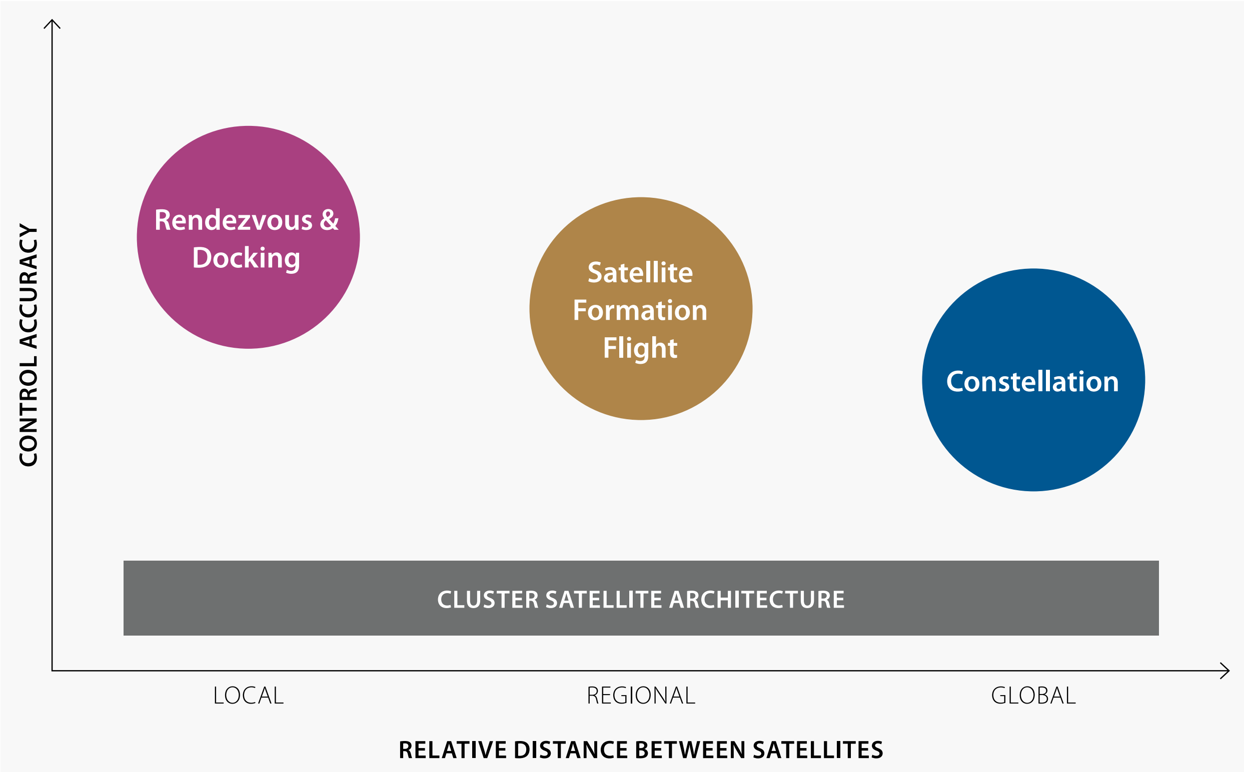

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Figure 1: Cluster space systems according to the relative distance and control sensitivity.[4]

and without orbit corrections, is on the order of months, whereas for a similar cluster at 700 km in LEO is on the order of years. For this reason, the mission requirements and service life must be established from design and the architecture must be created to operate at the optimum orbital altitude.

A satellite cluster can undertake complex space missions such as rendezvous, formation flight, or stereo imaging. In addition, a recent development includes its use in delivering full-range internet services. Their increased presence in LEO will naturally increase the risk of orbital collisions.

Recently, NATO's sensitivity to supporting operations with small satellites in LEO has increased.[5] Throughout NATO, work continues to train personnel in Space matters and establish dedicated, compatible Space organizations.

Recognizing the increased importance of small-satellite cluster architectures, their study and research has become a top priority for international communities, such as NATO, as well as for most nations.[6] The progress brought in by research is accelerating Space Power's impact ushering real effects at the tactical, operational, and strategic levels. Space Power will enhance any country's armed forces and the overall strategic effectiveness of NATO and all its stakeholders.[7]

Pros and Cons

The advantages satellite clusters provide include a greater field of view and coverage as opposed to a single satellite, while three-dimensional earth observation and interferometry studies can also be undertaken.

In a satellite cluster, each component is smaller, lighter, and easier to construct; hence, the cluster satellite concept is less costly and less complex than a single large satellite. Moreover, the failure of a single satellite is not as critical to the overall mission, because the failed satellite can be easily replaced by a spare.

Some constraints and challenges for the cluster satellite concept, such as operational and environmental complexities, mission performance particularities, and interoperability issues, are largely due to the diversity of its autonomous systems and sensors.[8]

Most important in cluster satellites applications is to design the formation architecture according to user and space mission requirements. Each satellite's motion parameters and relative geometry disturbances must be precisely determined during in-flight formation.[9] In addition, the use of high-performance, visual sensor-based systems makes it possible to capture the motions of spacecraft and space debris and predict their relative vector states, which can subsequently be used for rendezvous, docking,[10] or navigation to determine orbital motion and avoid collision.[11]

Control of Cluster Geometry

Cluster satellite architectures are generally subdivided by distance and control precision. Flight formation is a specific subset of distributed space systems, distinguished by interspace and control precision. There is a diversity of formation architectures from local satellite formation systems, with ten metres between satellites, to global architectures spaced up to thousands of kilometres.[12]

The main cluster satellite architectures, represented in Figure 1, can be defined as:[13]

- *Constellation architecture:* comprised of many satellites flying in similar orbits, properly distributed in time and position to ensure the desired ground coverage. The satellites are controlled individually from ground control stations. A real-life example is the Global Positioning System (GPS) constellation architecture in LEO.
- *Satellite formation flight architecture:* A mission- and observation-oriented multi-satellite architecture with relative position controlled by closed-loop internal control systems. It is generally used for shorter separation distances, unlike the constellation architecture.
- *Rendezvous & docking architecture:* is the most sensitive in terms of control accuracy and distance between space platforms. The control sensitivity increases proportionally with the decrease in the relative distance between space platforms.

It is important to determine the geometric shape of the cluster architecture and the number of satellites required. Once the formation is achieved, differential perturbation accelerations will gradually destroy the initial geometry. Depending on users' needs, the active control of the formation's relative geometry is a requirement to counter orbital distortions, particularly within LEO.

A relative Guidance, Navigation, and Control (GNC) system should be used to maintain the formation for the desired period. Typically, a closed-loop control scheme is implemented on the satellites, as shown in Figure 2. Guidance information is provided by ground stations or by autonomous internal sensors of other satellites within the cluster.

Relative navigation is concerned with optimum estimates of the position and speed of a platform relative to another.[14] There are many traditional applications, such as Global Navigation Satellite System (GNSS) and Inertial Navigation System (INS), either integrated or ground based. These applications require extra connectivity between components and the sensor fusion sections.[15] The newer applications use optical and image processing, as well as sensing and tracking models, which aim to reduce complexity and increase accuracy.

Operating Considerations

The following examples present some of the operating challenges when dealing with small-satellite systems.[16]

Determination of attitude and position. Using miniature sensors to interpret a satellite's position, interpret measurements, and determine the relative distance between satellites with sufficient accuracy.

Autonomous control of position and attitude. The deviation between the measured position and the attitude towards a target will be determined to establish the corresponding corrective manoeuvres. There is limited contact with the ground control stations due to the orbit's nature; hence, real-time reaction capabilities must be utilized.

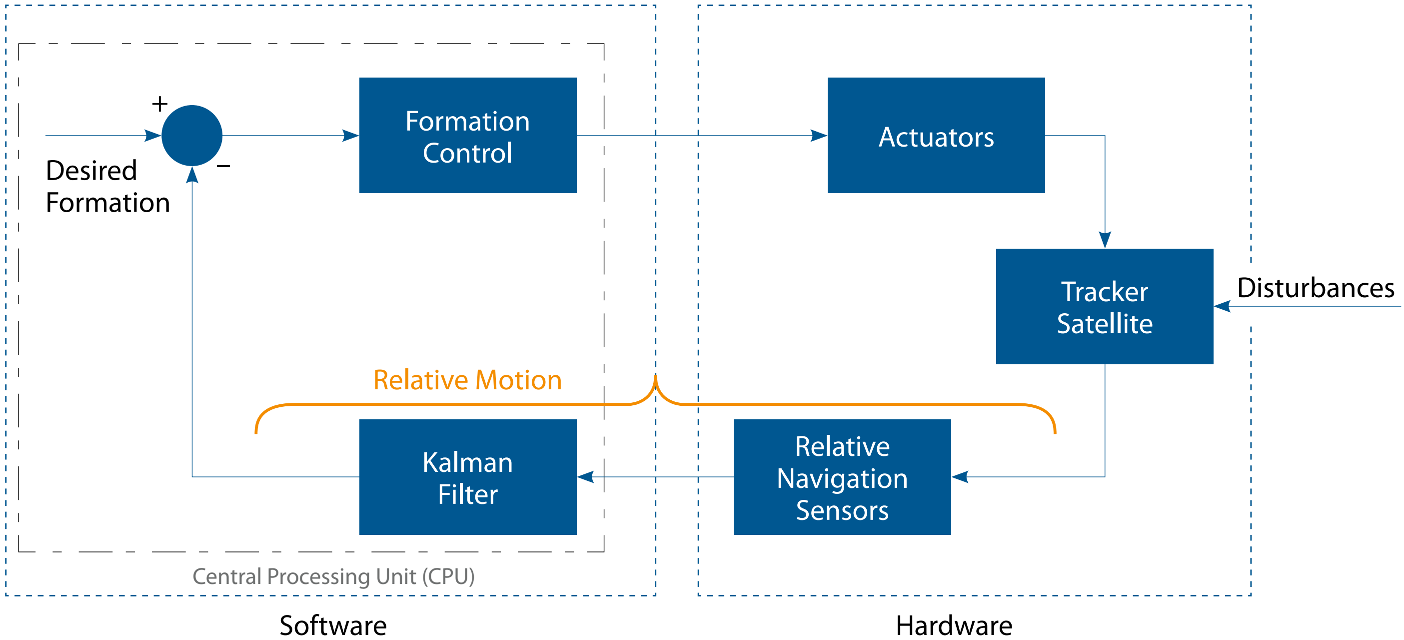

Figure 2: Closed-loop control scheme of follower satellite.

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Operation of cluster satellites architectures. Control of satellite formations requires coordination of ground control interactions, which are characterized by signal propagation delays and disconnections, and built-in autonomous reaction capabilities. It is sufficient to implement the position-control function capability only for a leading satellite and the follower satellites will adjust their positions to the leader accordingly to the desired constellation geometry.

Small satellites may use different methods for their relative navigation while in formation flight. Traditionally, GNSS & INS integration is used to find the relative position.[17] Without data from the ground or the GNSS, the satellite will have to navigate using only on-board calculation data, usually accomplished by internal sensors.[18]

Cluster satellites architecture with GNSS-based sensors. These small satellites use GNSS signals to maintain the cluster's geometry by determining their positions relative to each other. This method is in use and has been proven in many cluster satellite space missions. Still, due to the limited GNSS coverage, only satellites in LEO use this traditional method of relative navigation.

Cluster satellites architecture with vision-based sensors. Visual-based sensor systems are preferred to reduce dependency on external systems.[19] While GNSS is used for close-formation satellites in LEO or Medium Earth Orbit (MEO), it cannot be used in 'deep space' missions. New sensor technologies must be developed to reduce costs and payload weight while avoiding the performance limits of the GNSS.

Relative navigation algorithms. To control the tracker satellite, its relative state is estimated using algorithms that observe and predict its movements, such as the monocular Simultaneous Localization and Mapping (SLAM) algorithms,[20] Kalman filters,[21] Gaussian Sum,[22] and Particle Filters.[23]

Results and Discussion

Paramount to choosing a cluster satellite architecture is satellite miniaturization, thus avoiding the restrictive limitations of single-satellite space missions and saving launch and construction costs. A comparison between single satellite architectures and cluster satellite systems is shown in Table 1.

Single Satellite Architecture	Cluster Satellite Architecture
Hard to separate into pieces	Easy to separate into pieces
Highly interdependent system dynamics	Dynamics are loosely coupled
–	Time-scale separation is apparent
Physical dispersion adds little benefit	Physical dispersion can be used to great effect
Sequential tasking is adequate/optimal	Simultaneous tasking has great utility
–	Sequential tasking is inadequate
Information transfer is costly/inadequate	Information transfer is not costly
–	A global information state can be maintained
Orbital limitation makes communication difficult	Local information is adequate
–	Lags and latency are accepted

Table 1: Comparison of single and multiple satellite architectures.[24]

GNSS-based and visual-based sensors are the two main approaches used to estimate the relative vectors of cluster satellites. A comparison between them is shown in Table 2.

The traditional approaches, which use GNSS sensors, have proven their reliability and sensitivity in LEO space missions. Technological developments have made it possible to use visual sensors to counter the coverage limitations of GNSS; hence, their usage is expected to increase in future space assets.

Conclusion

Cluster satellite architectures have become a necessity, rather than a choice, in terms of space mission requirements and cost-effectiveness. In addition, to secure their place in space, many nations are developing space architectures that are broadly inclusive, cost-effective, and interoperable with other nations' space assets.

Furthermore, the challenges of realizing a cluster satellite architecture can be overcome through a combination of high-corporate experience, knowledgeable manpower, and technological capabilities. Economic considerations and the need for competent personnel should motivate countries to work in concert to develop cluster satellite architectural formations. NATO stands out as the most suitable community to foster interoperability. Considering that cluster architectures will continue to increase in the future, it is necessary to emphasize the development of new sensors and utility payloads.

Today, when private companies create their own cluster satellite architectures and space forces, NATO creates a Space Force entirely reliant on allies' space systems. Considering the space and earth-based operational environment requirements and the inherent operational advantages of each, it may be time for NATO to enhance its organic space architecture by acquiring and operating its own assets and support operations in all domains for all its forces and components.

Other issues that need to be addressed globally are space security and satellite collision risks. The risk of a collision, resulting from the uncontrolled use of Space, is increased by the growing number of satellites operated by civilian companies and organizations. Global organizations, such as NATO, should acknowledge the intensive use of Space and take the necessary measures to minimize the risks associated with the uncontrolled use of Space.

NATO has to continuously adapt to keep up with the developing technologies in the Space domain. Within the scope of space missions, these small, dynamic, and cost-effective cluster satellite architectures will inevitably replace the single, large satellites. The question is, when will NATO embrace this challenge and work to maintain its technological advantage in Space?

Visual-Based Sensors	GNSS-Based Sensors
Green Method (no energy dissipation required).	Based on electromagnetic wave energy.
Wide sensor requirements viewing range.	Satellites and GNSS coverage is required.
Short-distance solutions.	Relatively long-distance solutions.
The additional inter-satellites link is not required, provided autonomous solutions.	Link between satellites is required.
The relative motion sensitivity depends on the sensor sensitivity.	The relative motion depends on the GNSS information sensitivity.

Table 2: Comparison of visual- and GNSS-based sensors within cluster architectures.[25]

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Lieutenant Colonel PhD Tuncay Yunus Erkec

graduated in 2003 from the Turkish Air Force Academy with a BSc in Electronic Engineering, in 2017 from the Istanbul Technical University with a MSc, and in 2021 had his PhD at the National Defense University, Hezarfen Aeronautics and Space Technologies Institute for Space Sciences. He currently works as an assistant professor in the same department. He served as a NATO FOB operations officer and acting commander and was awarded a NATO Meritorious Service Medal. He holds a patent on satellite design and is a Commercial Pilot license holder. His research topics include satellite design, satellite attitude and orbit determination, Kalman filtering, relative navigation, and formation satellite flight.

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Defining the Swarm

Challenges in Developing NATO-Agreed Terminology Across All Domains

By Lieutenant Colonel André Haider,
GE A, JAPCC
By Lieutenant Colonel Andreas Schmidt,
GE AF, JAPCC

Introduction

In recent years, the terms 'swarm' and 'swarming' have been among the most prevalent buzzwords in the uncrewed[1] systems' community, to include not only air vehicles but also land, maritime, surface, as well as underwater variants. However, what is a swarm or which common capabilities it needs to possess has not been officially defined. NATO's uncrewed aircraft community has recently begun developing definitions for the above terms to eventually formalize the respective terminology for official use, but quickly stumbled as different communities have diverse interpretations and perspectives of what constitutes a swarm. Hence, an air-centric definition may not be well suited for the other domains.[2]

This article aims to outline the challenges and provides food for thought when discussing a future definition of 'swarm' and its related terms in the context of uncrewed vehicles.[3]

Purpose of a Definition

Every definition of terminology needs to fulfil a purpose; otherwise, it is not relevant and does not need to be defined. For instance, Remotely Piloted Aircraft (RPA) are defined as 'unmanned aircraft that are controlled […] by a pilot who has been trained and certified to the same standards as a pilot of a manned aircraft'.[4] Hence, using the term RPA indicates a certain degree of pilot qualification requirements to operate the aircraft. In the same fashion, it needs to be agreed which conditions and purposes are served by the definition, i.e. in which situations it is needed.

The challenge with defining 'swarm' is that the applicable uses differ significantly and that the defining parameters for one use may not be relevant to another. To outline this challenge, some examples are described below.

The Employment Use. Using a swarm for achieving a military effect is based on the military problem that needs to be solved. Swarm functions will only be employed when they promise a military benefit compared to other solutions. The desired effect will be, by nature, in line with the capability requirement definition and, therefore, within the legal framework of the procurer. Fielding swarm technology and operating it in line with applicable national and alliance legislation, Rules of Engagement, and Tactics, Techniques and Procedures will likely require a definition that provides statements about the military capabilities, modes of remote operation, means of command and control, as well as the level of human interaction.

The Developer Use. Potential swarm functions need to be well understood to identify military employment benefits from a developer's perspective. Developing swarm technology and achieving the correct execution of swarming behaviour will likely require sophisticated levels of autonomy and artificial intelligence applications that enable a human to operate the swarm as a whole but do not require (or even allow) the control of any individual swarm entity. Therefore, a definition for this use is likely to be focused on the level of autonomy, its technical implementation into the hardware and software, and the adaptation of the swarm function into its system.

The Counter-Swarm Use. When observing and defending against a swarm, the level of autonomy or the means of command and control is not that important. From this perspective, the sheer number of entities, their observed behaviour, and their assumed swarm capability are the most relevant problems and thus, the defining elements, regardless of whether the swarm entities are manually controlled or operating autonomously. The challenge of identifying if a larger group of entities qualifies as a swarm increases with the complexity of the displayed swarming behaviour.

There may be other cases where a definition of the term 'swarm' may require deviations or alternatives to serve its purpose. To solve this dilemma, there are two options. First, develop multiple definitions for every use and, second, find a common denominator that could serve all (or at least most) uses. As multiple definitions bear the risks of confusion and misunderstanding between the different user communities, the second option is preferred. Each user community may later append its specific requirements to the general definition as subcategory terms, similar to the RPA, which is a subcategory under the overarching definition of 'Uncrewed Aircraft'.

Common Denominator

This brings us to the challenge of identifying a common denominator for an overarching swarm definition. Commonalities can be found primarily by observing a swarm, particularly its behaviour, no matter if it comprises air, land, or maritime vehicles and regardless of whether the swarm behaviour is actually performed or only perceived. Hence, an overarching definition should start with the outside appearance and visual perception of a swarm and not focus on its inner workings. The latter may be covered and distinguished in subcategory terms.

Swarming Behaviour

In open-source research, numerous definitions of swarming behaviour are available, but they principally describe the same idea, often including swarm intelligence as a prerequisite. For example:

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Of note, 'multiple swarm elements' does in principle mean that any number of units greater than one, which are engaging in swarming behaviour to increase the collective capability of the overall units, can be considered a swarm. Since the identification of swarming behaviour is hardly possible without dedicated systems, it is advisable to consider multiple entities that seemingly operate together as a swarm unless proven otherwise. Higher numbers amplify the benefits of swarming behaviour. Also, the individual entities do not need to be identical, but simply compatible to solve a military problem as part of a swarm.

- 'Swarming is the phenomenon in which a large number of individuals organize into a coordinated motion. Using only the information at their disposition in the environment, they are able to aggregate together, move en masse or migrate towards a common direction.'[5]
- 'Swarm intelligence is the study of decentralized, self-organized systems that can move quickly in a coordinated manner.'[6]
- 'In swarm robotics multiple robots collectively solve problems by forming advantageous structures and behaviours similar to the ones observed in natural systems, such as swarms of bees, birds, or fish.'[7]
- 'Swarm Intelligence has been derived from the natural swarm behaviour of animals which can be defined as the collective behaviour exhibited by the animals of same size, aggregating together to solve a problem which is essential for their survival. Swarm Intelligence can be defined as the emergent collective intelligence of groups of simple agents.'[8]

The common denominator of all the above definitions is the 'coordinated movement' of the individuals forming the swarm. Collective intelligence is also mentioned as a key element in realizing this behaviour; however, an observer will not be able to determine if a swarm's **coordinated movement** is based on collective intelligence or through another means of control. Thus, collective intelligence is a secondary attribute to consider in an overarching definition and needs to be covered by subsequent terminology. Of note, future technologies, including artificial intelligence and machine learning applications, may enable an observer to determine if a large group of entities possesses extra swarm functions that could pose an increased threat. Therefore, 'collective intelligence' or similar identifiable swarm functions may be included in the definition.

Number of Individual Swarm Elements

Another key element of a swarm, inferred by the above definitions, is the number of entities involved without specifying a distinct minimum. Is there a threshold to be crossed to divert from traditional grouping schemes such as squadron, flight, or package to qualify as a swarm? Again, we have several options.

1. Classify any formation of two or more elements as a swarm.

2. Define a swarm as a group of individual elements that exceeds a specific number, higher than the aforementioned traditional groupings.

3. Avoid any specificity and leave this detail again to subsequent taxonomy levels.

To refrain from being too restrictive and allow for subcategories, the last option is recommended. The term **'multiple swarm entities'** expresses the proposed 'non specificity' quite well and will be used for this reason later in the article.

Spatial Distribution

The aforementioned observable characteristics, 'coordinated movement' and 'multiple swarm elements', do not imply a minimum or maximum distance between the individual swarm entities. There are already concepts of employing widely-distributed uncrewed aircraft to relay radio communications or provide internet connectivity to remote places. The distance between the individual air vehicles may be hundreds of kilometres to provide coverage over a large area. Even on a smaller scale, swarm entities may operate in a coordinated manner within only a few hundred metres of distance to observe an area or attack larger targets with multiple impact points. Whether such entities follow predetermined and uncoordinated patterns or perform coordinated actions may remain hidden for an observer, if the group (or swarm) cannot be surveyed in its entirety. The spatial distribution of a swarm is therefore not a qualifying factor for an overarching definition and would unnecessarily limit its application, although these characteristics may play a role in counter-swarm activities and be defined in subsequent terminology.

Human Interaction

The different levels of autonomy and the corresponding levels of human interaction are broadly discussed when talking about swarm technology. For example, the higher the level of autonomy, the lesser the requirement for human input during the actual mission. A swarm displaying a complete set of swarming behaviour is very likely to be at the upper end of the autonomy tiers, reducing the necessity for human interaction to a minimum. It can also be assumed that this human interaction applies to the whole swarm, to control the overarching swarm functions and not the individual swarm entities. However, the level of autonomy and the level of human interaction can hardly be determined when observing a swarm of individual air, land, surface, or sub-surface vehicles and is therefore not a relevant factor for an overarching 'swarm' definition. To not limit the applicability of the definition, these characteristics should be described in a sub-term, such as 'Smart Swarm', 'Autonomous Swarm', or similar wordings, as they certainly have applicability in research and development, swarm employment, and probably for legal purposes.

Swarm Capabilities

It is often assumed that forming a swarm enhances or generates a capability unachievable by individual systems alone. A swarm can be considered a system of systems which can execute predesigned functions and deliver one or more (military) effects. These effects benefit either directly from the swarming behaviour or indirectly from the composition of individual system capabilities as a combined swarm function. This benefit needs to be clearly understood from a capability requirement, employment, and defensive perspective, and can be linked to other military use definitions. In general, swarming behaviour is the foundation of any swarm capability. However, swarm capabilities may vary significantly depending on the type of systems used and, in contrast to swarm behaviour, cannot be observed but only assumed until performed. Therefore, capability statements are not deemed suitable for an overarching definition and should also be covered by subordinate terminology.

spatial arrangements between the individual swarm elements into subcategories.

Multiple. Swarms may consist of a handful or even hundreds of elements, but at least more than one. The unspecific term 'multiple' allows the definition to work

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Definition Proposal

A definition depends on the swarm's intended use. As swarm applications offer various uses, this article recommends beginning with an overarching definition and covering the individual use attributes in subordinate terminology.

The following is an overarching definition proposal that covers and supports all military domains and their respective uncrewed systems and, subsequently, each term of the definition is explained.

A swarm is a formation of multiple entities, which display coordinated behaviour towards an objective.

Formation. This should indicate the spatial correlation between swarm elements, while purposefully not describing their specific organization further. This leaves room to classify the various distances and

for all types of swarms, regardless of their participating elements. Defining a specific number will also be difficult for any subordinate terminology. One distinction could be made between 'countable numbers' in a small swarm and 'uncountable numbers' in a large or massive swarm which may be helpful, for example, to distinguish the threat when a human or technical system is simply overwhelmed by the approaching entities.

Entities. It covers all categories of uncrewed vehicles, including air, land, surface, and sub-surface systems. This term can also work for the cyber and space domains if coordinated actions of computer programs or satellite systems are future options for NATO to pursue. Subordinate terminology could be considered, for example, Uncrewed Aircraft Systems Swarm (UASSw)[9] or Uncrewed Surface Vehicles Swarm (USVSw).

Display Coordinated Behaviour. The inner workings and technical mechanisms of arraying a swarm can differ and for some uses the definition may not even require a review of these internal characteristics. The common denominator identified in this article is the swarm's behaviour consisting of coordinated manoeuvres and actions that can be observed. It deliberately does not state how those coordinated actions are achieved. The technical means to enable swarm functionality can be expressed in subsequent terminology, such as 'autonomous swarm' or 'intelligent swarm'.

Towards an Objective. This serves the military context, as it can be assumed that a swarm is always directed towards an objective to achieve its given mission goal, ranging from simple site survey, intelligence, surveillance, and reconnaissance, to strike or suicide missions. This may not be relevant outside the military context and could be left out.

Conclusion

Finding an agreed definition for 'swarm' is a difficult challenge as there are plenty of uses across all military domains and civilian applications. The only solution for achieving broad acceptance of a swarm definition within NATO is to identify the common denominator of all swarm characteristics, reduce the definition to a minimum, and leave the specifics for dedicated uses to subordinate terminology.

1. NATO is in the process of adopting the term 'uncrewed' instead of 'unmanned' to reflect the terminology changes in the civilian aerospace domain, especially the International Civil Aviation Organization (ICAO) and the Federal Aviation Administration (FAA). Although not yet officially included in NATO terminology, JAPCC is using 'uncrewed' from now on.
2. The Joint Capability Group Unmanned Aircraft Systems (JCGUAS) initiated the development of a definition proposal for 'swarm' at their Spring 2021 meeting. JAPCC supports that initiative by hosting several online workshops for the JCGUAS, aiming at an agreed terminology proposal until Autumn 2022.
3. This article is a revised version of an initial food for thought paper on the subject matter that was provided to the JCGUAS in Spring 2021 to assist in the initial terminology discussion.
4. The full definition reads 'An unmanned aircraft that is controlled from a remote pilot station by a pilot who has been trained and certified to the same standards as a pilot of a manned aircraft'.
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9. So far, no NATO-agreed abbreviation for the term 'swarm' is available. It is proposed to just add 'Sw' at the end of all respective acronyms. Simply adding an 'S' creates confusion with the abbreviation for 'system'.

Lieutenant Colonel André Haider

is an artillery officer by trade with over fifteen years' experience in command & control and operational planning. He is the JAPCC's Uncrewed Aircraft Systems Subject Matter Expert for more than ten years and represents the JAPCC in the NATO Joint Capability Group Unmanned Aircraft Systems and NATO Counter-UAS Working Group. He authored multiple studies, books, and articles with regard to operational and legal issues of UAS and C-UAS.

Lieutenant Colonel Andreas Schmidt

joined the German Air Force in 1993. After attending Officers School, he studied Computer Science at the German Armed Forces University in Munich. Since 1998, he built up an extensive background in Ground Based Air Defence, particularly the PATRIOT weapon system. He started as a Tactical Control Officer and subsequently held positions as Reconnaissance Officer, Battery Executive Officer and Battery Commander in various PATRIOT units. Furthermore, he had two non-consecutive assignments in Fort Bliss, Texas. In between, he had an assignment as the A3C in the former Air Force Division. Currently, he is the Integrated Air and Missile Defence / Ballistic Missile Defence SME at the JAPCC.

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Collective Defence in the Space Domain

Confining the Ultimate War in Threatened Space

By Major Arda Ayan, TU AF, JAPCC
By Major Brian Ladd, US Space Force, JAPCC

Introduction

Space is fundamental for contemporary national security missions. NATO perceived the significance of Space in military operations and for national security by formally designating Space to be an operational domain in December 2019. As the world's biggest security alliance, NATO relies on Space for a wide range of activities from intelligence gathering and navigation to tracking forces around the globe and detecting missile launches.[1]

The Space domain is becoming increasingly congested with new non-state actors and corporations constantly joining the race. This domain is incredibly dynamic, sparking new discussions[2] on regulating commercial, military, and technological activities in outer space.

The security of space assets will have a defining impact on future terrestrial conflicts. Therefore, defending the final frontier has become a primary concern for NATO. The number of orbiting satellites and satellite mega-constellations is augmenting the Alliance's capabilities and serves a vital role in the Alliance's economic interests.

Bearing in mind the founding principles of NATO,[3] this article will discuss the threats that the Space domain faces today. It will also outline the potential forms an attack in Space could take and the avenues NATO has to respond to such an event.

Military innovation advancements call for the improvement of extant or development of new concepts of operation and military approaches, primarily

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aiming to gain asymmetric advantages against potential adversaries. The Alliance is constantly adapting to new threats and, today, Space is a new frontier for defence.

Alliance's decision to declare Space a new operational domain can be considered a recognition that Space is no longer a peaceful domain. Although NATO diplomats denied that the Alliance could be in a war expanding to Space, declaring Space a domain initiated debates on NATO's eventual use of space weapons to defend against enemy missiles or to destroy satellites.

The circumstances mentioned below are the *sine qua non* of NATO's role in the extraterrestrial environment:

- NATO does not own or operate any space assets in orbit, but is reliant on its member nations to utilize national assets to manage operations and defend Space.
- Not every nation has direct access to Space or for some it is very limited. For example, the United States (US), Germany, France, and Italy have multiple assets in space and could potentially respond in the event of an attack in space. Other nations' access to space is limited and would likely look for Alliance's support to respond if their access to space is threatened.
- NATO believes in the peaceful use of Space, and is not developing counter-space capabilities.

Dealing with the 5th Domain Threats

Space is an extraterrestrial global domain where any created effect can have terrestrial consequences. A conflict in orbit could threaten or compromise space assets and access to space services. Therefore, the range of technologies developed and tested as weapons in space by various countries create political, humanitarian, or military concerns. Although the 1967 Outer Space Treaty defines the use of space for peaceful purposes,[4] space has been used by militaries since Sputnik for the same reason: security.

Today more than 4,000 active satellites are orbiting the Earth and over half of these are operated by NATO countries to provide a wide range of services like the mobile phone industry, banking system, weather forecast, Global Positioning System, communication, intelligence sharing, and the detection of missile launches. Any threat targeting space assets may impact national and Euro-Atlantic prosperity, security, and stability and could challenge NATO as any terrestrial conventional attack.

In response to a crisis, NATO will operate in areas that require space capabilities wherever terrestrial logistics are not available. Therefore, NATO and its member nations recognize that Space is a domain that must be utilized to succeed in current and future operations. Any potential adversary may quickly note the advantages that Space offers to the Alliance and consequently space systems are becoming high-priority targets.

The increasing potential threats to the Space domain must be considered from a broader perspective. Can Intelligence, Surveillance and Reconnaissance (ISR), Position, Navigation and Timing (PNT), or communication satellites be regarded as weapons? They are not weapons. Nevertheless, due to their contribution to military activity, they could be considered military targets by potential adversaries. For instance, they can be used to attack other satellites by being positioned too close or colliding, thus affecting other on-orbit satellites and causing international unrest.

The risks for the space systems include any threats that can impact the system's control, reliability, bandwidth availability, security, flexibility, or affordability. These threats can be unintentional (natural hazards or man-made debris) or intentional (Directed Energy Weapons (DEW), electronic, cyber, or kinetic attacks).[5]

All the threats listed in Figure 1 can limit or degrade a nation's ability to operate its space capabilities. However, three of the threats can cause a catastrophic loss of capabilities and are the most likely to form the basis for a discussion leading to an Article 5 declaration. Hence, these three critical threats (yellow highlighted) will be the focus of this article.

Kinetic physical is described as the attempt to physically damage a satellite by a direct strike, detonating a warhead near it, or incapacitating a relevant ground station. Weapons that target the satellites in orbit are known as Anti-Satellite (ASAT) weapons.

- *Direct Ascent Anti-Satellite (DA-ASAT):* This type of ASAT weapon has been tested by China since 2007[7] and most recently by Russia in 2021[8] against their defunct satellites as a demonstration of capabilities. It is especially dangerous because it produces a debris cloud that increases the possibility of future satellite collisions.
- *Co-Orbital ASAT:* This counter-space capability is an attractive alternative to the DA-ASAT as it limits the resulting debris and it can be challenging to determine the intent of the possible threatening satellite. A Co-Orbital satellite can be utilized in all orbits and can cause a range of effects, from disruption to total loss of capability.

A *High Altitude Nuclear Explosion (HANE)* is the most detrimental of all potential attacks as it can eliminate all space capabilities in a particular orbit. This form of attack will impact all space capabilities irrespective of ownership, including those owned by the attacker, and therefore it is primarily considered a last resort attack.

Potential NATO adversaries have and are in the process of developing the full suite of counter-space capabilities. In the event of an attack in the Space domain, NATO must be prepared to respond, given that Space is one of its critical domains.

Article 5, the Cornerstone of the Treaty

In case of an attack, the North Atlantic Council could and would invoke Article 5 and take the necessary measures.

NATO's essential and enduring purpose is to safeguard the freedom and security of all its members using political and military means. Collective defence is at the heart of the Alliance and creates a spirit of solidarity and cohesion among its members.[9] As stated in the original manuscript:

'The Parties agree that an armed attack against one or more of them in Europe or North America shall be considered an attack against them all and consequently they agree that, if such an armed attack occurs, each of them, in exercise of the right of individual or collective self-defence recognised by Article 51 of the Charter of the United Nations, will assist the Party or Parties so attacked by taking forthwith, individually and in concert with the other Parties, such action as it deems necessary, including the use of armed force, to restore and maintain the security of the North Atlantic area.

Any such armed attack and all measures taken as a result thereof shall immediately be reported to the Security Council. Such measures shall be terminated when the Security Council has taken the measures necessary to restore and maintain international peace and security.'[10]

This article is complemented by Article 6, which stipulates:

'For the purpose of Article 5, an armed attack on one or more of the Parties is deemed to include an armed attack:

	Ground-Based	Space-Based	Threat to Space Segment					
			SATCOM	ISR	PNT	SSA	METOC	SEW
NATURAL								
Meteoroids		○	○	○	○	○	○	○
Space Weather		○	○	○	○	○	○	○
KINETIC PHYSICAL								
Direct Ascent	○		○	○	○	○	○	○
Co-Orbital		○	○	○	○	○	○	○
DEW								
Laser Damage	○	○	○	○	○	○	○	○
Blinding/Dazzling	○	○		○			○	
High Power Microwave		○		○			○	
HANE	○		○	○	○	○	○	○
ELECTRONIC								
Uplink Jamming	○	○	○		○			
Downlink Jamming	○		○	○	○			
Spoofing	○				○			
CYBER								
C2 Seizure	○		○	○	○	○	○	○
Data Corruption	○		○		○			
Data Intercept	○		○		○			
OTHER								
Sprayers		○	○	○	○	○	○	○
Deception (Decoys)	○			○				
Space Debris		○	○	○	○	○	○	○

Figure 1. An overview of the possible effects of space threats over functional space areas.[6]

- *on the territory of any of the Parties in Europe or North America, on the Algerian Departments of France, on the territory of Turkey or on the Islands under the jurisdiction of any of the Parties in the North Atlantic area north of the Tropic of Cancer;*

- *on the forces, vessels, or aircraft of any of the Parties, when in or over these territories or any other area in Europe in which occupation forces of any of the Parties were stationed on the date when the Treaty entered into force or the Mediterranean Sea or the North Atlantic area north of the Tropic of Cancer.'*[11]

Space-Capable NATO Nations

In June 2021, NATO declared that 'The Alliance is not aiming to develop space capabilities of its own and will continue to rely on national space assets. NATO's approach to space will remain fully in line with international law.'[12] NATO has no intention to put weapons in space.

NATO's in-orbit dependence on partners is clear and finding the perfect balance between national security needs and Article 5 requirements is paramount. Since Allies retain full command and control over their assets, regardless of the particular situations, when there is a conflict of interest between national and organizational priorities, parties should understand and properly prioritize the need from a global perspective, thus truly manifesting the strength of the Alliance.

National space support to NATO cuts across the full spectrum of Space functional areas. Currently, twenty NATO nations own operational satellites. However, Figure 2 lists only those space capabilities owned by the leading Space-capable nations.[13]

'Unus pro omnibus, omnes pro uno' in Space.

In addition to the capabilities listed in Figure 2, the US also provides Shared Early Warning (SEW) to NATO. Moreover, the US provides all spacefaring nations with Space Situational Awareness (SSA) data to enable peaceful and safe operations in space.

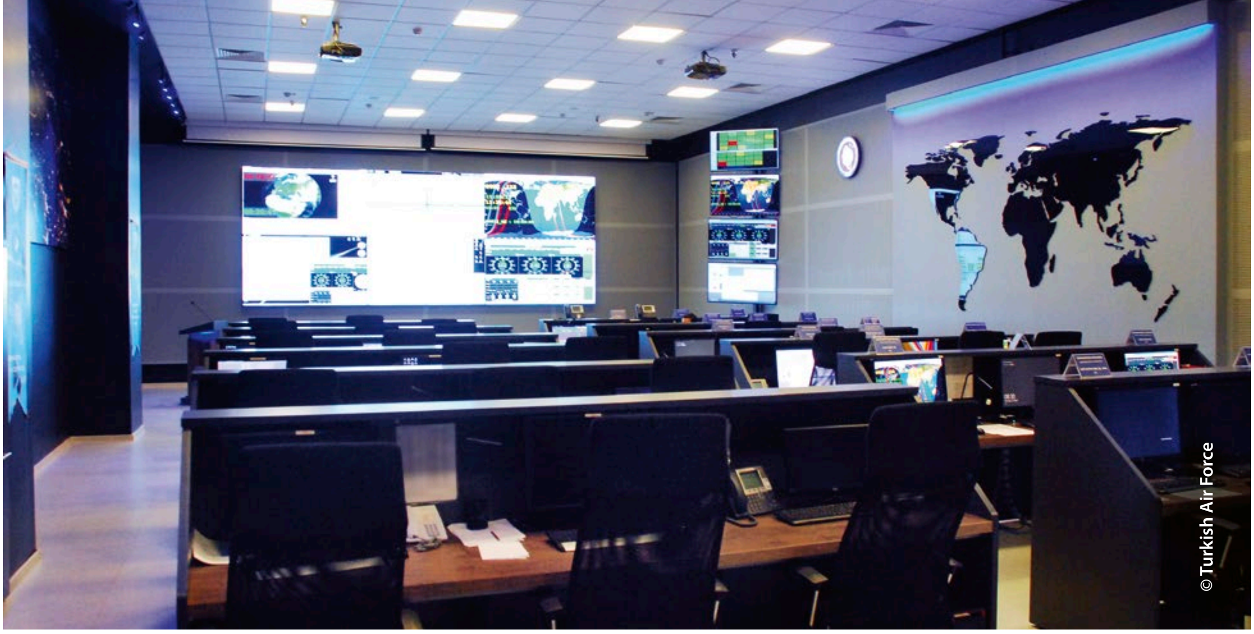
In recent years, an increasing number of NATO member nations have stood up specific military Space elements, such as the US Space Force, the United Kingdom Space Command, the French Space Command, the German Space Command, and the Italian Space Command. Moreover, in 2020 the new NATO Space Centre was established to provide operational Space support to NATO, while in 2021 the NATO Military Committee approved the establishment of the NATO Space Centre of Excellence in Toulouse, France.[15] Turkey is also endeavouring to establish a Space Command soon and utilize their rising number of space professionals, expand their capabilities with PNT, SSA, and METOC and integrate strategies, objectives, and projects according to their national space policy.

Recommendations

It is relevant to state that Article 6 does not explicitly mention space assets as stipulations of an armed attack. However, at the 2021 Brussels Summit, NATO recognized that attacks to, from, or within Space present

	Capabilities					
Nation	SATCOM	ISR	PNT	SSA	METOC	SEW
Canada	○	○	○	○	○	
France	○	○	○	○	○	
Germany	○	○	○	○	○	
Italy	○	○	○	○	○	
Norway	○	○	○	○	○	
Spain	○	○	○	○	○	
Turkey	○	○				
UK	○	○	○	○	○	
USA	○	○	○	○	○	○

Figure 2. Space systems owned by the main Space-capable NATO nations.[14]



Turkish Air Force Reconnaissance Satellite Command Satellite Operations Centre.

New USSF Combined Space Operations Centre, Vandenberg Space Force Base.

a clear challenge to the security of the Alliance and could lead to the invocation of Article 5 of the North Atlantic Treaty. The key term here is *could.* As there is currently a grey area on what would constitute an attack in Space, consequently leading to an Article 5 declaration, this article proposes one of two solutions.

1. Amend Article 6 to include attacks on space assets.
2. Add a new article to limit the response to an attack in Space only with a response in the same domain.

The first solution has the downside that it can lead to the activation of responses from all domains to what many would only consider a conflict in the Space domain. The loss of a space capability is assuredly an attack on a nation's security; however, losing an asset in space is not a loss of life. Therefore, if Article 5 were declared it would be critical to limit the Alliance's response to only those actions that prevent any domain crossover and reduce the risk of loss of life.

On the other hand, the second solution benefits from the lack of fatalities and prevents conflict escalation. However, limiting the response to the Space domain has its drawbacks, like endangering other in-orbit assets and restraining the use of cyber-domain capabilities.

Conclusion

NATO is fully aware of the fact that Space is essential to coherent Alliance deterrence and defence. Continuous and secure access to space services, products and capabilities is essential for the credibility of the Alliance's posture, management of that posture, and the conduct of the Alliance's operations, missions and other activities.[16] The US recognizes that Space is a domain that needs to be defended, and NATO should consider adopting the same perspective. There is no doubt that NATO and its allies will proceed in the most appropriate manner. At this point, it may be helpful to keep in mind that time flows faster in the Space environment and that our potential adversaries are watching the successes of the Alliance in the Space domain with an eagle eye from the front row.

'Nations that cannot protect their skies can never be sure of their future.'
Mustafa Kemal Atatürk

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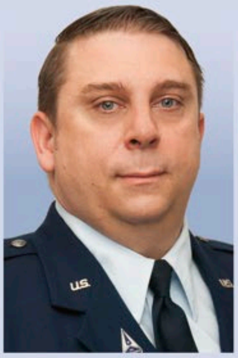
Major Arda Ayan

graduated from the Turkish Air Force Academy in 2005 with a Bachelor's degree in Computer Engineering and was stationed as a SHORAD (Short Range Air Defence) officer at the 6th Main Jet Base Anti-Aircraft Battalion Command. Following his Master's degree in Space Sciences, in 2014 he was appointed as a satellite mission planning officer in the Reconnaissance Satellite Battalion Command within the Air Force Intelligence Department. In charge of Göktürk-1 and Göktürk-2 ISR Satellites, he took on the duties of Satellite Control Officer and Satellite Operators' Supervisor, respectively, in the first and only military Earth observation satellite command and control centre in Turkey. Since August 2021, he serves as a Space SME at the JAPCC.



Major Brian Ladd

graduated from Bowling Green State University in 2005 with a Bachelor's degree in History and received his commission by AFROTC. His first tour was at the 4th Space Operations Squadron at Schriever AFB in Colorado Springs, CO, where he was a Satellite Operator of the MILSTAR communications system. His other operational tour was as the Liaison Officer at RAF Fylingdales Strategic Missile Warning Radar. He has completed many Space Staff assignments at Joint Base Pearl Harbor-Hickam, Vandenberg AFB, and Offutt AFB. He transitioned to the US Space Force in October 2020. Since June 2021 he serves as the Chief of Cyber and Space Readiness at the JAPCC.

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The Next 'Small Step for Man' in the Metaverse

Operating Between Virtual and Physical Worlds

By Major Fotios Kanellos, GR AF, JAPCC

Introduction

On 28 October 2021, when Meta[1] founder Mark Zuckerberg presented the Metaverse, a series of interconnected virtual worlds capable of entirely transforming the way we communicate, few people were able to understand whether this was just another rebranding and marketing hype or the next evolutionary step in our lives; the creation of an advanced, networked Virtual Reality (VR). One of those who realized the importance of this new technology was Bill Gates, the Microsoft co-founder, who foreshadowed during a Ted Talk event the threat posed by an infectious virus[2] five years before the actual COVID-19 pandemic outbreak.

'Over the next two to three years, virtual meetings will shift from the 2D camera image grid format to a 3D space with a digital avatar',[3] he said in his yearly blog in December 2021. With the confidence of his almost prophetic past predictions, Bill Gates saw that people will meet virtually in the near future, in interconnected digital environments with the help of 'avatars',[4] realistically simulating an in-person meeting.[5]

Due to the pandemic, humankind has been forced to make monumental leaps in technology use. Technology has grown, changed, and accelerated so rapidly and widely in the last two years, where normally it would have taken decades. In such a challenging environment, are organizations, such as NATO, capable of reviewing long-established practices and adjusting traditional operating procedures to maintain their strategic edge?

Next Big Thing

During the 1990s, the use of the Internet, computer networking, and digital communication proliferated worldwide and forever changed the way we live and interact. These technological innovations constituted the epitome of the 4th Industrial Revolution[6] and the beginning of the Information Age. Since 1991, the World Wide Web has become publicly accessible, going beyond the United States government's and universities' borders. It needed less than a decade to expand globally. In comparison, the first 2G cellular network was released in that same year and less than 30 years later, 5G networks are up and running.

Today, what is happening gradually is not only the Internet's transition from two-dimensional (2D) websites to three-dimensional (3D) web spaces,[7] but also the emergence of its limitless successor, the Metaverse. In this Metaverse world, when it is fully developed, people will appear as self-designed avatars. They will engage in everyday activities, like conversations and flirting, going as far as squabbling and even to the extremes of espionage. A limitless virtual reality will allow people to inhabit and control characters that will move and socialize in a digital space similar to a multiplayer online game. This means that we could not only play games, talk, watch movies, attend events, shop, stroll, and do virtually things similar to those in the real world, but also interact with the real world in countless and unpredictable ways.[8] Like the universe, the Metaverse includes both space and time and is not only a form of matter, but also a form of energy. In particular, the Metaverse 'is about a time when basically immersive digital worlds become the primary way that we live our lives and spend our time'.[9] The line between the real and the digital worlds will be increasingly blurred, and the Metaverse will become a vital venue to operate socially and resolve disputes or conflicts.

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The infrastructure and processing power is still insufficient to replace the existing 2D internet with the envisioned immersive, networked, 3D virtual world. Although hundreds of hyperscale cloud data centres[10] have already been built worldwide to efficiently support robust, scalable applications,[11] the fully formed Metaverse with its countless live, synchronous connections will need many more investments by the big data-producing companies such as Alphabet, Amazon, Facebook, Apple, or Microsoft. Surprisingly, the most influential factor that accelerated and revolutionized the way we work and interact with each other is undoubtedly the COVID-19 pandemic.[12]

According to Bill Gates' predictions, the pandemic's impact on digitization will take at least another decade to be realized. In the meantime, new technologies and products must be developed to become the ultimate gateways into the Metaverse (VR headsets, smart glasses, haptic gloves) and enhance people's interactions and shared experiences. Simultaneously, due to the exponentially growing number of interconnected devices, the attack surface and the potential entry points for hackers will drastically increase, undermining the effectiveness of the existing network intrusion detection systems.

The convergence of the physical, augmented, and virtual reality in a shared online world, the 'embodied internet', will offer unprecedented interoperability to its 'citizens' and unforeseen security challenges to governments and institutions. No single company or authority can run the Metaverse exclusively; thus, various multi-players and groups will operate it decentralized. Digitization is here to stay and will affect the way people work, learn, or entertain, as well as the way national and military interests compete and fight.

The Future Operating Environment

In such a digitized world, which gradually and steadily shifts towards becoming a virtual one, defence and security policies and strategies have to adapt accordingly. Emerging and disruptive technologies can generate both risks and opportunities. Globalization, communications advances, and dual-use technologies, such as artificial intelligence, quantum computing, machine learning, big data management, blockchain networks, autonomy, and biotechnology, have the potential to threaten NATO's military technological superiority. The future defence environment requires not just new technologies, but also new ways of approaching and leveraging these technological challenges.

The new information realm, reinforced by advanced 'Social Media 2.0'[13] applications, does not only lead to technological developments, but also to sociological changes. The dissemination of fake news coupled with information warfare campaigns can influence, manipulate, demoralize, or even radicalize public opinion and behaviour, undermining the trust in the democratic institutions and processes.

The Alliance understands that it 'cannot succeed in tomorrow's fight with yesterday's approach'.[14] NATO needs to continuously transform 'to shape and contest the environment and to keep the edge over our adversaries and competitors, now and in the future'.[15] The operational environment changes at high speed. The future military battlespace is widening, demanding more collaborative, efficient, digitized, secure, and cyber-resilient efforts across the Land, Air, Maritime, and Space domains.[16]

The NATO Multi-Domain Operations approach recognizes and effectively addresses the increasingly blurred geographic and organizational boundaries, under the purview of the pervasive information environment. A modern decision-making cycle needs to be able to create decisions at the speed of relevance, despite the constantly growing volume of information that has to be processed. The traditional environmental and cultural domain boundaries need to be broken down[17] as the domains' current static, fragmented, command and control (C2) architectures prove insufficient. The new approach should leverage the future cloud-like combat environment by instantly sharing and transmitting data across multiple communication networks, from both the physical and non-physical domains.

Today, billions of interconnected smart devices and sensors, like 'everything-to-everything' networks,[18] need web-based, decentralized, and agile C2 architectures to enable the decision-making process to adapt rapidly and autonomously to the mission's environment with minimum human intervention. In addition, brain-computer interfaces can transform the brain's low-electrical activity to strong digital signals to be analysed by external devices and translated into commands and desired actions.

Decision-makers, irrespective of their hierarchy level, need 'access to information to allow for simultaneous and sequential operations using surprise and the rapid and continuous integration of capabilities across [multiple] domains.'[19] Leveraging new technologies will help rapidly understand the battlespace, direct forces faster than the enemy, and deliver synchronized multi-domain effects.[20] If all the necessary information is available in time for each process (planning, deployment, engagement),[21] then the so-called 'information superiority' can be achieved, leading to better situational awareness and decision advantage.

Conceptualizing the Virtual Meta-Domain

As the physical environment is progressively transformed into live, data-bound, digital replicas to create the so-called Digital Twins[22], where every physical object is linked to a virtual counterpart, new operational platforms and advanced technologies need to be applied in the formulated, mixed-reality ecosystem. The ongoing convergence of physical and digital objects has the potential to revolutionize and stimulate future military operations by instantly leveraging all allocated sensors and effectors across the physical and non-physical domains and synchronizing the desired effects accordingly.

'A digital twin-based approach offers the prospect of consistent, reusable, and available data'[23] to advanced military systems and platforms providing previously impossible benefits to supply chain management, testing, training and experimentation capabilities, as well as, introducing immersive mission planning processes. Gamification principles[24], based on advanced simulations with a high level of authenticity and credibility, can 'improve the complex and costly process of military flying training by incentivizing the training process.'[25]

Moreover, the integration of operational platforms based on advanced analytics, data modelling, ingenious simulation, autonomous control, brain-computer interfaces, and live interactions can transform and accelerate the decision-making process while ensuring its accuracy. Information superiority and effective situational awareness are essential in a dynamic, multi-domain combat scenario. All assessed and relevant data needs to circulate at high speed and be disseminated to the key actors to enable forces to 'be informed [...] and act as one.'[26]

Of course, the adversary will try to interrupt the Alliance's kill chain, inject effects into the operational planning process and compromise the accuracy of its machine learning algorithms to control and manipulate the contested area and prevail in any kinetic fight. In the future warfighting environment, the C2 chain needs to be flexible, resilient, and interconnected. Accessibility, agility, and flexibility are essential operational demands in a fast-paced, multi-domain, fully digitized environment. Content, products, and services must be available on demand from sustainable devices through a low-cost, robust, networked infrastructure.[27]

A transition to the 'Meta-Domain Operations' concept where avatars, 3D models, mixed-reality, and spatial environments are the main asset classes, implies that interoperability limitations between platforms and networks are overcome. The traditional interoperability standards cannot support the new media types in an integrated way, nor can they account for large amounts of unstructured data. All organizations, including the military ones, will have to adopt new ways of thinking and undergo rapid digital transformations across all aspects of their culture, structure, operations, and services to move into the Metaverse. The various Metaverse platforms need to provide convenient, portable, functional, and secure systems and interfaces to enable seamless transitions.[28]

Conclusion

As technology and digitization continue to change and develop, assets and data in the Metaverse need to continuously evolve throughout their lifecycle and be accessible from any platform in an expanded and open ecosystem. By employing best practices through emulation, migration, and representation, the Metaverse can be highly effective, resilient, and desired in supporting the modern military environment. The Meta-Domain environment, structured under a cyber-hygiene ecosystem, considered with its virtual capabilities and brain-computer interfaces, can produce synchronized and decisive effects in Multi-Domain Operations.

For NATO to keep the edge over its competitors and maintain its military forces and assets at a high preparedness and capability level, it will have to re-think how it sees the world, both in a physical and a virtual sense. Without agility, digital interconnection, data sharing, and collaboration of all dimensions in the cognitive, physical, and virtual domains, superiority cannot be achieved in an extended and mixed future battlespace. In order for NATO to make its transition to a truly digital force, the Metaverse will be the ultimate tool to reach this path. ●

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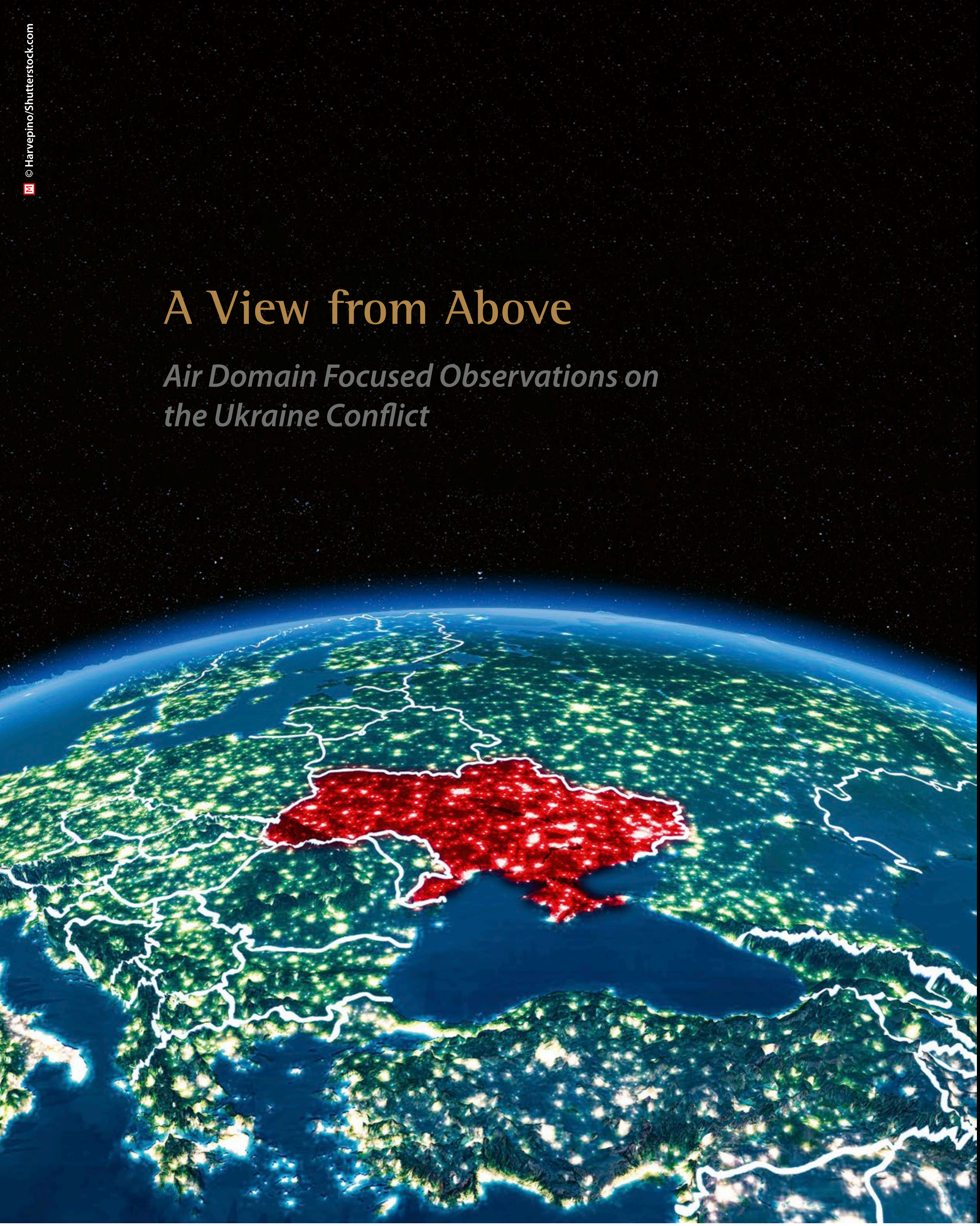
Major Fotios Kanellos

graduated from the Hellenic Air Force (HAF) Academy in 2003 as an Electrical Engineer specializing in Telecommunications and Computer Science. He holds three Master's degrees: Technical-Economic Systems from the National Technical University of Athens (NTUA), Environmental Sciences from the University of Patras, and European and International Studies from the National and Kapodistrian University of Athens.

He served as an inspection engineer for T-2 C/E aircraft and system engineer for the T-6A Flight Simulator at the Hellenic Air Training Command in Kalamata. His previous appointment was at the HAF Support Command managing IT and Cybersecurity projects. Currently, he is the Cyberspace SME at the JAPCC.



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A View from Above

Air Domain Focused Observations on the Ukraine Conflict

Although the conflict between Russia and Ukraine is still ongoing, with no prospect for termination of the hostilities in the foreseeable future, some initial observations can be made with respect to the air domain. These initial observations are made by the JAPCC's Subject Matter Experts (SMEs) and are just that, not to be seen as comprehensive, all-encompassing assessments. No firm analysis can be performed yet, because of the diffuse information situation. Therefore, these observations are based solely on data collected from open sources and cannot be validated. However, we deem these observations as consequential and relevant, whilst open for further analysis once definite information becomes available. This article focuses on four areas of interest: the Russian Anti-Access/Area Denial (A2/AD) strategy, resilient basing, helicopter operations, and Space.

The Russian A2/AD Strategy

Following Russia's annexation of the Crimean peninsula in 2014, there was renewed interest in the Russian strategy and the development of Russian military capabilities. On the one hand, there was the 'Gerasimov doctrine', which had been published the year before the annexation and described a new, non-linear form of warfare (the so-called 'hybrid warfare'). On the other hand, the introduction of new weapon systems expected to enable an A2/AD strategy and give Russia a certain level of dominance over a future battlefield.

The developments above have received much attention from military strategists, scholars, and reporters. For NATO as well, the recent years have been dominated by the challenge of properly dealing with the alleged Russian hybrid and A2/AD threats, which had a real impact on exercises and training. While joint and strategic headquarters focused on countering a hybrid threat, Air Forces were trying to develop ways to bust the A2/AD bubble effectively.

However, in the current Ukraine conflict, Russia seems to fail to apply the A2/AD strategy to its full advantage. This is demonstrated by, among other things, Russia's persistent difficulties in achieving air superiority over large parts of the battlefield. In trying to figure out the reasons behind this failure, we can certainly consider technological, organizational, operational, or logistical (economic) shortcomings.

For the time being, one can only speculate why Russia seems unable to implement an A2/AD strategy with the military capabilities at its disposal, such as long-range air defence weapons, air-launched cruise missiles, or hypersonic missiles. Firstly, from the organizational and operational sides, there seems to be a lack of cooperation and coordination between the different branches of their armed forces. For example, the Russian Air Force mostly employs its weapons from a cleared airspace outside the battlefield. This could be due to insufficient (joint) training, improper (multi-domain) planning, interoperability issues, and perhaps even mistrust between the different branches of the armed forces. In addition, the exposed communications failures, which have been widely reported in the mass media, could also be a contributing factor.

Secondly, it could be the case that Russia is trying to implement its A2/AD strategy, but is unable to dominate the battlefield due to technological and logistical shortcomings. For example, the Russian stocks of precision-guided munitions may be limited due to their high production costs and magnified by the effects of international sanctions imposed on Russian weapons manufacturers. Furthermore, modern missile defence systems seem unable to detect and eliminate targets fast enough, and the various long-range missiles do not appear to be as precise as expected.

Resilient Basing

The JAPCC is currently working on a major project looking at the issue of Resilience. The Oxford English Dictionary's definition of 'Resilience' is: *'The capacity to recover quickly from difficulties.'* The concept of the Resilient Basing project is to capture the roles and functions of any given airbase and then look at what threats and hazards may be ranged against that airbase. Analysing the roles and functions of a facility and then identifying its weaknesses will provide an insight into what aspects of any output must be made more robust to make activity more resilient against prevailing threats and hazards. This methodology can be applied to any asset irrespective of role and function, so it is in reality a joint tool.

Russia's inability to dominate the battlefield from the outset would lead to a fight for supremacy in a contested environment. Russia does not appear to operate effectively in a contested area, resorting to the destruction of entire areas indiscriminately.

The project aims to examine the complete spectrum of conflict from Baseline Activity and Current Operations (BACO) to activity at the Maximum Level of Effort (MLE). The spectrum of threats to be explored includes both kinetic and non-kinetic threats from various actors, ranging from terrorist organizations to near-peer adversaries, while also considering hybrid threats. This, in turn, is set in the contemporary Multi-Domain Operations (MDO) environment.

This project has considerable relevance when considered in the context of the current conflict in Ukraine. No matter which side you examine, both have been impacted by the actions of the other in terms of attacks on infrastructure, which have been all the more effective given that the targeted infrastructure was lacking in Resilience. The lesson appears to be simple - nations have forgotten the 'art of war' or, in relation to the Air Component, we have forgotten how to operate our airbases as fighting platforms! We have lived through the epoch of so-called 'wars of choice' and are now being confronted once again by competition, if not yet a war, where if we fail to learn or re-learn the lessons of the past, the outcomes will change our way of life. The point is clear; our adversaries will exploit any lapse in Resilience.

As JAPCC publications have highlighted on many occasions, NATO Joint Air and Space Power is what our adversaries fear most – it is NATO's asymmetric advantage. However, while investing in the latest platforms is essential, if we do not invest equally in their enablers and create resilient systems, then we will fail. To return to a point made in the recent JAPCC white paper 'NATO Force Protection on a Knife Edge – A Think-Piece', we are in grave danger of our platforms being little more than flaming piles of very expensive scrap at the end of a runway, if we do not adopt the principles of Resilient Basing.

Helicopters Operations – Missing Out on a History Lesson

Prolonged helicopter usage in Afghanistan taught us that helicopters that fly low and slow are too vulnerable to Small Arms Fire (SAF) and Man Portable Air Defence Systems (MANPADS). For this reason, helicopter operations in Afghanistan were mostly executed above 5000 ft. During the 2014 Donbas war, Ukraine lost ten helicopters (Mi-8 and Mi-24) to SAF, heavy machine guns, and MANPADS fired from the separatists' side. This might have given them the (renewed) insight into low and slow-flying aircraft vulnerability. But also how to protect or, if necessary, destroy them.

Where many nations use the American AH-64 Apache gunship, Russia uses the Ka-52 Alligator attack helicopter as its counterpart. The Ka-52 helicopter is a formidable machine, but as recent history shows, Ukraine is not intimidated. Ukraine claims to have destroyed at least four Alligators in the early days of the war against Russia.

When the Russian invasion of Ukraine began, Russia planned first to take the capital, Kiev. Hoping to overwhelm Ukrainian defences, a group of 34 helicopters used for this invasion (on the morning of 24 February) was escorted by Ka-52 Alligator attack helicopters. The invasion did not work according to plan as the Ukrainians shot down the Alligators with heat-seeking air defence missiles and the attack was repulsed in heavy fighting. Pilots did not expect to be shot at by missiles fired from MANPADS.

The overall (under)performance of the Ka-52 must be frustrating for the Russians. Their highly rated gunship is falling victim to shoulder-fired missiles. However, they should have known, taking into account the difficulties encountered against insurgent-fired Stinger missiles during the Soviet war in Afghanistan. A missed history lesson.

Space Domain-Related Considerations

During the initial stages of the conflict in Ukraine, how events unfolded in the Space domain was a vital aspect, which has also affected the way the conflict is currently unfolding. Three items stood out, the cooperation between Russia and the international community with the purchase of the Soyuz rockets, the limited denial of the electromagnetic spectrum by Russian forces, and the commercial space industry stepping into the fray to augment Ukrainian forces.

In the early stages of the conflict, the majority of the international community spoke out against the invasion of Ukraine, specifically the United States, the European Union, and the United Kingdom. These countries, among others, are partners within the International Space Station (ISS) and regularly use Russian Soyuz rockets for their space programmes. Due to the diplomatic outrage, Russia responded by declaring that any nation that spoke out against the conflict would no longer be able to purchase Soyuz rockets. This has far-reaching consequences for emerging Space programmes as they rely on the Soyuz rockets to place satellites into orbit. As a result of this threat, the aviation and space industry has already made proposals for Soyuz replacement.

It was widely anticipated that Russia would dominate the electromagnetic spectrum by actively denying the Ukrainian defence's GPS and voice communications usage. As the conflict progressed, it became evident that Russia was hesitant to employ its electronic countermeasure capabilities as they were unable to operate their own forces. In fact, many frontline reports suggested that Russian forces were commandeering cell phones from Ukrainian civilians to conduct operations. This was a massive unforeseen benefit to the Ukraine defence, as it enabled listening and tracking of their communications.

Lastly, the impact of the commercial space industry cannot be understated. A Ukrainian official requested via Twitter to Elon Musk for access to his Starlink Communication system. Within hours, Elon Musk reconfigured his system, and within a couple of days, truckloads of Starlink equipment arrived in the country. When reports of Russia's interference surfaced, Elon Musk developed a software update within days that eliminated the interference. The Starlink system has been a crucial tool for Ukrainian defence. In addition to the communication assets, the Intelligence, Surveillance, and Reconnaissance (ISR) community stepped up its support by delivering high-resolution intelligence to the Ukrainian defence forces, thus enabling constant visibility of Russian troop postures.

These observations are based on open source information, should not be considered definitive, can serve as the basis for further analysis and evaluation, and are the product of the collaborative work of the following JAPCC members:

Colonel Erik Rab
Air Operations Support Branch Head

Wing Commander (ret.) Jeremy Parkinson
Force Protection SME

Lieutenant Colonel Marco Sampimon
Exercise Support and Analysis and
Lessons Learned SME

Major Brian Ladd
Space SME

Major Eelco Tolsma
Joint Rotary Wing and
Joint Personnel Recovery SME

MDO: What's in a Name?

Transforming JAPCC's JADO Project to Better Support ACT's MDO Concept

What started years ago as an operational answer to counter the Anti-Access/Area Denial (A2/AD) threat has become one of the most challenging endeavours NATO has ever undertaken. The challenges posed by the 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 on how to ensure the effective and efficient implementation of the military Instrument of Power (IoP). The increased competition in the new Cyber and Space domains raised new complexities to be dealt with during operations.

The future operational concept must ensure that NATO's core tasks can be executed across the full spectrum from peacetime to conflict and under all conditions. Therefore, NATO has to have the capability to continuously understand the changing environment and consequently develop strategies to sustain an operational advantage.

It was apparent that this multi-domain concept could only be achieved by going 'beyond Joint'. 'Joint', in its current form, does not allow for the planning and creation of sufficient effects in time or confront the opponent with an adequate number and type of dilemmas unless a structured and comprehensive response is provoked.

The only way to achieve this is to prepare, plan, orchestrate, and execute synchronized activities at scale and speed, across all domains and environments, together with the other IoPs and our partners.

During the last few years, NATO and different nations explored the (im)possibilities of a multi-domain concept. Depending on the overarching national approaches to defence strategies, several variations on the multi-domain concept were developed and fielded. In essence, all approaches had the same objective: to synchronize activities across domains and environments leading to timely converging effects.

The most significant differences in the approaches are which domains are considered for inclusion and how far other IoPs and partners are integrated into the planning and execution processes. The United Kingdom leans more towards an all of government approach where all national IoPs and stakeholders are synchronized to ensure a comprehensive and holistic effect generation. The United States and France adopted a more military-centric approach, with solid interfaces to coordinate activities with other IoPs or stakeholders.

ACT has issued the NATO definition of Multi-Domain Operations (MDO) and an appropriate vision statement. The JAPCC has to be aligned with NATO's policy, therefore, the JAPCC has adapted to the approved NATO terminology and strategic vision for NATO's warfare model. With this approach, NATO focuses on the military IoP, with a solid coordination and collaboration interface to all relevant non-military actors and partners. The JAPCC has always favoured this way of thinking. Coordination and cooperation across the civil-military boundaries is challenging, as ambiguities in authority or national priorities can create friction, which is counterproductive and diminishes the effects being pursued through MDO.

For the JAPCC, the scope of the related MDO project (formerly JADO) will not change. It includes critical nodes, desired capabilities, Command and Control (C2), and, most importantly, the training necessary to optimize the leadership model and promote Alliance-wide understanding. The project will help identify the requirements and capabilities to move from our current state of interoperability to a level of seamless integration able to conduct NATO MDO in the future. ●

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JAPCC at the 2022 COE Marketplace

The 2022 COE Marketplace was held at the NATO HQ in Brussels from 10 to 11 May 2022. The purpose of the event was to provide an opportunity for all staff and national personnel at NATO HQ to meet representatives of the 28 NATO-accredited Centres of Excellence (COEs) and recognize, understand, and embrace the value of the expertise, support, and advice provided by these NATO-affiliated organizations to the Alliance. This annual event has full support of NATO's leadership and is an excellent opportunity for the COEs to promote their work and share the products and outputs delivered to NATO on behalf of their Sponsoring Nations.

General Paolo Ruggiero, Deputy Supreme Allied Commander Transformation, highlighted the fundamental contribution of the Centres of Excellence in his opening remarks and stated that the COEs are without a doubt 'a powerful force multiplier thanks to their unique and qualified expertise, wide outreach capacity and distinctive position outside the NATO Command Structure'.

The JAPCC 'exhibition wall', books, and publications were highly appreciated by the visitors and served to highlight the message, mission, and achievements of the JAPCC, since its inception.

Overall, the JAPCC team engaged with many visitors and seized this opportunity to present the work and activities of our Centre and share best practices with participants from NATO HQ, ACT and other COEs.

The COE Marketplace is definitely an excellent forum to gain formal recognition at the highest levels of NATO's leadership, while also demonstrating the value the JAPCC brings to the Alliance. ●

Beyond the Blue

JAPCC's Journey Through the 5th Operational Domain

Joint Air Power Competence Centre's journey to Space began at its establishment in 2005 with the recognition that Space is a critical domain, enabling the application of military power across all domains. The 2008 whitepaper 'NATO Space Operations Assessment' was the first major JAPCC publication on NATO's challenges in Space. Since then, our centre has remained NATO's catalyst for the improvement and transformation of Joint Air and Space Power, which has evolved dynamically and rapidly over the years. NATO's recognition of these developments culminated with the declaration of Space as the 5th operational domain in 2019, alongside air, land, maritime, and cyberspace, and the adoption of the first Space Policy in 2022.

To contribute to JAPCC's mission of providing key decision-makers effective solutions to Space Power challenges, JAPCC's Programme of Work includes, but is not limited to, the following areas:

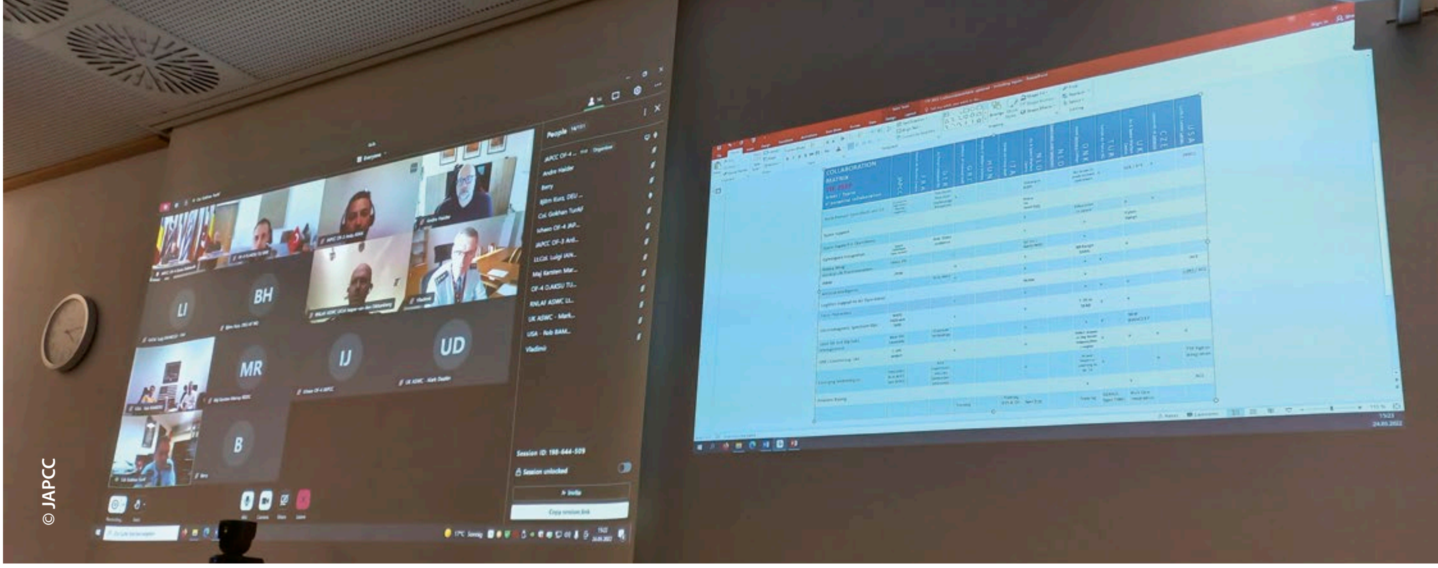
As an active contributor to the NATO Bi-Strategic Commands Space Working Group, since its establishment in 2012, JAPCC provides advice and guidance to this community which is the main focal point for Space-related activities within NATO.

JAPCC provides Space lectures and presentations, and addresses all Space-related Requests for Information. Our JAPCC Space SMEs take an active role as part of the NATO Space Team and the JAPCC OPFOR Team during most high-level NATO exercises.

As the Department Head for Space for the last six years, JAPCC became the coordinating body of the Global Programming Process to pursue the best available Education and Training (E&T) opportunities. In this role, JAPCC led the Annual Discipline Conference, drafted the corresponding Discipline Alignment Plan, supported the revision of the Space Basic Course and the creation of the Space Support Coordinator Course at NATO School Oberammergau, and provided Space educational support.

As part of their engagement activities, JAPCC Space SMEs cooperate with a variety of NATO organizations and agencies from the NATO Command Structure to the NATO Force Structure, EU, nations, and other institutes (e.g. they participate in several Space-related NATO Science and Technology Organization studies). In 2021, the discipline's name changed from 'Space support in operations' to simply 'Space', thus becoming one of the 28 E&T disciplines included in the Bi-SC Comprehensive List of Disciplines. Moreover, a French proposal to act as a Framework Nation for a NATO Space COE was accepted by NATO. Following this development, the Department Head duties will progressively be transferred from the JAPCC to the NATO Space COE, while SHAPE will remain the Requirement Authority for Space. In accordance with the accreditation process, this transition will occur at the end of 2022.

The establishment of the NATO Space COE in Toulouse does not suggest that the JAPCC will abandon its vital role in providing Space expertise. The responsibility of the new NATO Space COE will be the overall integration of Space in all warfighting domains, the so-called 'Joint Space', whereas the JAPCC will focus on Space's role in Air Power. As the reliance on the Space domain grows steadily, it is paramount that Space remains part of JAPCC's portfolio, thus recognizing the strong relationship and interdependence between the Air and Space domains. ●



Joint Air and Space Power Think Tank Forum 2022

Unified and Connected!

Against the backdrop of the Russian invasion of Ukraine, and unfortunately still influenced by some remaining restrictions of the Covid pandemic, the traditional 'national summit' of the Joint Air Power Competence Centre (JAPCC) brought together again experts from national commands, think tanks, academia, and warfare centres in the annual Think Tank Forum (TTF). During a two-day virtual conference in mid-March, partners discussed diverse developments in the Air and Space domains and shared their perspectives and approaches. Together, we identified areas of common interest and potential collaboration to collectively contribute to both national and NATO forces' transformation.

The TTF is one of two main forums organized annually by the JAPCC. Whereas the TTF is a meeting of national entities, the JAPCC's Joint Air and Space Power Network Meeting brings together representatives of international organizations working on solutions to Air and Space Power challenges.

Attendees of the TTF came from the JAPCC, the German Air Force Command, the Hellenic Air Force Command, the Hungarian Faculty of Military Science, the Italian Air Force Staff, the Dutch Air and Space Warfare Centre, the Danish Royal Defence College, the Turkish Air Force Headquarters, the British Air and Space Warfare Centre, the Czech University of Defence, and the United States Air Force's Curtis E. LeMay Center. The positive trend of increasing national defence budgets provided an optimistic basis to discuss topics like state-of-the-art technologies, capabilities development and procurements, effective employment of national Air and Space forces, as well as structures and processes that support interoperability across multiple domains.

The identified projects, common interests, and lines of effort were recorded in a 'collaboration matrix'. This matrix provides situational awareness of potential fields of cooperation, identifies relevant points of contact, describes the methodology of collaboration, and serves as a feedback tool.

It was a commonly held view at the TTF that our nations face similar challenges today. Therefore, the opportunities to interact with others are of utmost importance. Forums like the TTF effectively foster cooperation and collaboration that will enhance our common defence. The current situation proves that the ability to cooperate and act together in a synchronized manner, is a key factor enabling smart solutions to reinforce NATO deterrence and defence.

JAPCC Hosts the First Two IAMD Training Sessions

NATO SBAMD Common Education and Training Initiative

Surface-Based Air & Missile Defence systems, formerly called Ground-Based Air Defence, have become a scarce asset within NATO's inventory since the end of the Cold War. Only a few countries have focused on this essential part of NATO's Defensive Counter Air capability, and it has remained the NATO standard for their forces. As proven by the recent crisis in Ukraine, these few countries have the right perspective.

Exercises like Tobruk Legacy, initially a Czech Republic and Slovakian initiative which morphed into the Ramstein Legacy NATO exercise series, and the Dutch/German Joint Project Optic Windmill are still cherished events which practice the art of true Integrated Air & Missile Defence by combining land- and air-based systems in an integrated air defence design. It was mainly during these exercises that it became clear that there was a need to reemphasize NATO Air C2 procedures to both Surface-Based Air Defence operators and Air C2 crews at the CRCs and the Air Component.

Perhaps we, as NATO, neglected the use of Ground-Based Air Defence as a DCA asset, but now in light of the changing geopolitical environment more

countries are re-emphasizing their Surface-Based Air Defence systems. We are increasingly utilizing Air Defence forces that deploy into the European territory and thus have to learn and adapt to NATO procedures.

Acknowledging these developments, in April 2021, Commander CAOC Uedem recommended starting a NATO Common Education and Training initiative, which was immediately embraced by AIRCOM. With the full support of AIRCOM, CAOC Uedem and the JAPCC created a framework in close cooperation with the GE/NE Competence Centre Surface-Based Air & Missile Defence (CCSBAMD) and the Integrated Air & Missile Defence Centre of Excellence to develop a Basic IAMD Training plan. The first two training sessions have already been hosted by the JAPCC this year (29–31 March and 3–5 May) and an additional training session is scheduled to take place from 8–10 November 2022 at the JAPCC in Kalkar, Germany.

JAPCC Announces Launch of New Updated Website

Modernized to Provide an Improved Reach and Experience for our Readership

After many months of hard work and dedication and with the help of Forever Design Agency Wesel, we are pleased to announce the launch of our completely transformed website! Along with a new look and feel, we have included some additional features that will make visiting the site easier and a more interactive experience.

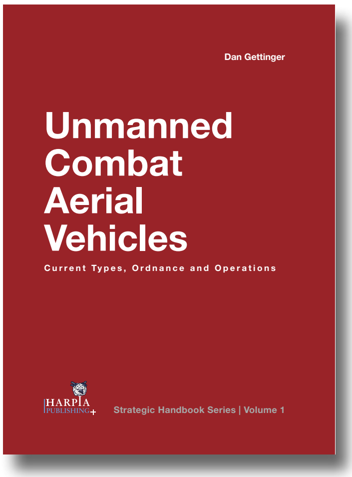
Our primary goal during the redesign process was to create a more valuable, user-centric, and responsive resource and engagement platform. Specifically, we wanted to make it easier for our users to locate useful information covering our events and publication archives from their desktop computers, tablets, and mobile devices.

For easier and faster access, we have reorganized and categorized all information by warfighting domains, military disciplines, and popular topics of concern. You can also pinpoint the information you are looking for on our website through an advanced search function.

We hope you enjoy our new look!

Visit us online (www.japcc.org) and for any suggestions, questions, or comments, please contact us at contact@japcc.org.

'Unmanned Combat Aerial Vehicles'



By Dan Gettinger; Harpia Publishing L.L.C.; 2021

Reviewed by:

Maj Giuseppe Valentino, IT AF, JAPCC

Current Types, Ordnance and Operations (Strategic Handbook Series 1)

The evolution of technology and the development of Unmanned Combat Aerial Vehicles (UCAVs) in the last 20 years has revolutionized the capability of modern armies, especially in the areas of acquisition of information, target identifications, and real-time engagements.

This is the first volume of a Strategic Handbook Series that documents the UCAVs that are in development or already deployed, while also depicting the global operations in which they have been used. With definitions and classifications and setting out specifications of modern-day UAV manufacturers, this strategic book also provides readers a guide to navigating through today's world of armed UAVs and drones' munitions. The manual is organized logically, based on valid sources, and was devised in collaboration with the now closed Center for the Study of the Drone.

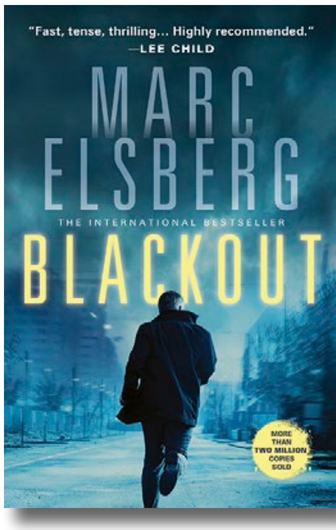
Although the technical data is not to be considered exhaustive, the manual represents a valid reference point for future developments in the UCAV sector, especially in light of the recent operations carried out by the UCAVs in the Russian-Ukrainian conflict. Moreover, the Unmanned Combat Aerial Vehicles Handbook represents an easy-to-read technical documentation for experts as well as non-experts.

'Blackout'

Blackout is an international bestselling thriller, describing a realistic scenario of a well-prepared coordinated attack against both the European and US power systems. Pre-installed malicious software is suddenly activated, creating misleading input into power grids' hardware, leading to arson and compromising several communications networks.

With no electrical power for nearly a fortnight, many unforeseen situations unfold. The resulting cascading effects illustrate the unpreparedness and vulnerability of both people and organizations, which causes many casualties due to various reasons. Whilst attempting to implement recovery measures, new unexpected pitfalls arise. Only with the help of a former Italian hacker, the security and counterterrorism agencies manage to prevent further disruptions and to capture a group of anarchists. Although this book was written in 2012, the key message is still valid. Our lives and activities are intertwined with technology which demand continuous access to electrical power. Current resilience measures may not be effective enough, if a long-lasting power outage occurs. Besides assessing pre-planned resilience attack concepts, an analysis needs to be conducted with respect to additional disruptive activities during a recovery phase. The Alliance can benefit from this terrifying non-kinetic scenario by projecting the presented disruptive events on their own organizations as a vector for enhancing their resilience.

I highly recommend that 'power users', in both the operational and the support domains, read this realistic thriller.



By Marc Elsberg; Sourcebooks Inc; June 2017

Reviewed by:

Lt Col Frans van de Weerd, NE AF, JAPCC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THE MULTI-DOMAIN ADVANTAGE
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MQ-9B SkyGuardian
MQ-9B SeaGuardian
MQ-9B is the world's most versatile multi-domain remotely piloted aircraft. Leveraging MQ-9B's open architecture system, operators can develop various SkyGuardian and SeaGuardian configurations by integrating and swapping advanced surveillance and defence technologies to accomplish missions over land or sea.
The UK Royal Air Force will be the first force to operate MQ-9B in the form of its new Protector RG Mk1.
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